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SCIENTIFIC AMERICAN SUPPLEMENT

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VOLUME LXXVI
NUMBER 1974

NEW YORK, NOVEMBER 1, 1913

10 CENTS A COPY
$5.00 A YEAR

The East Indian monitor (Varamus salvator).

THE NEW BERLIN AQUARIUM.—[See page 276.]

Tungsten Lamps of High Efficiency—II*

Nitrogen-Filled Lamps

By Irving Langmuir and J. A. Orange

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT, No. 1973, Page 263, October 25, 1913

THE first part of this paper outlined principles upon which radical improvements in the efficiency of tungsten lamps may be based.

It was shown that the desired improvement can be obtained by preventing evaporation of the filament or by preventing blackening of the bulb. By the introduction of considerable pressures of such gases as nitrogen or mercury vapor into the lamp the blackening can be practically avoided and the evaporation of the filament reduced very considerably.

By making use of these principles we have been able to construct practical tungsten lamps which, starting at an efficiency of about 0.40 watt per candle, have run over two thousand hours, the average efficiency during life being better than 0.5 watt per candle. It should be pointed out at the outset, however, that such a degree of improvement as this has been reached only in lamps taking large currents.

In this second part of the paper we will describe the methods by which these results have been attained.

The early experiments with lamps containing nitrogen at atmospheric pressure were made with ordinary single loop filaments of 0.005 and 0.010 in diameter placed in long heater lamp bulbs. These lamps were set up on life test at such a voltage that the temperature of the filament was 2,850 deg. K.

In order to compare these with ordinary lamps, similar lamps with evacuated bulbs were set up on life test with the filaments at the same temperature.

The nitrogen-filled lamps with the filaments 0.005 inch diameter gave an efficiency of 0.65 watts per candle and had a life of about 90 hours, whereas those with the larger filaments (0.010 inch diameter) gave an efficiency of 0.56 watts per candle and a life of about 300 hours. The bulbs opposite the filaments remained clear, although a slight brown deposit of tungsten nitride collected in the upper part of the bulbs. The candle power of these lamps remained above 80 per cent during their entire life, failure being due in every case to breakage of the filament after this had decreased considerably in diameter.

The vacuum lamps, on the other hand, gave an efficiency of 0.41 watt per candle, but the bulbs blackened rapidly, the candle power falling to 80 per cent in about 40 minutes. Since the filaments of the vacuum lamps burnt out after 2 to 5 hours whereas those of the nitrogen lamps lasted 50 to 100 times as long, it is evident that the rate of evaporation of the tungsten is materially reduced by the presence of the nitrogen.

These results indicated clearly the desirability of using a filament of large diameter. The larger filaments gave not only a better efficiency at any definite temperature, but also a much longer life. Thus doubling the diameter increased the efficiency from 0.65 to 0.56 and increased the life from 90 to 300 hours. The improvement in the efficiency, as was pointed out in the first part of this paper, is due to the relatively greater heat loss by convection from small wires. The life of the filament is determined largely by the loss of tungsten from the filament by evaporation and has been found to be dependent on the *relative* decrease in diameter caused by this evaporation. If the rate of evaporation per unit area from large and small wires were the same, the lives of various filaments run at a given temperature would be roughly proportional to their diameters. However, as the evaporation of tungsten in nitrogen is largely a diffusion process, it probably obeys laws similar to those of conduction or convection of heat from a wire; that is, for wires of small diameter, the actual amount of tungsten evaporated would be nearly independent of the size of the wire. The rate of evaporation *per unit area* would thus be approximately inversely proportional to the diameter. The relative lives of very small wires in nitrogen are therefore nearly proportional to the squares of their diameters.

DESIGN OF FILAMENT.

These results were decidedly encouraging, for both the efficiency and the life of the lamps can be improved by increasing the diameter of the filament.

It is, however, not desirable to use filaments of very large diameter if similar results can be obtained with smaller ones. The current taken by a filament increases approximately with the three-halves power of the diameter. Thus, for wires of the sizes used in the preceding experiments, the currents needed to maintain a temperature of 2,850 deg. were approximately:

Diameter.		Current.
Inches	Millimeters	Amperes
0.005	0.127	3.0
0.010	0.254	8.5
0.020	0.508	24.0

Unless very low voltages are used, the power consumed with the larger wires is so great that only very high candle power lamps can be made.

Therefore it was of vital importance to increase the effective diameter of the filament without decreasing its resistance, and various methods of doing this were tried.

This result may, for example, be obtained by using a tubular filament. The method which has thus far

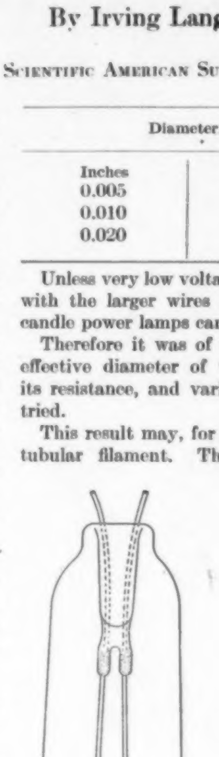


Fig. 1.—High efficiency nitrogen-filled lamp for low-voltage circuit.

Fig. 2.—High efficiency nitrogen-filled lamp for low-voltage circuit.

proved most satisfactory, however, is to wind the filament into the form of a tightly coiled helix.

The use of a helically wound filament presents several very interesting features. The life of ordinary single loop filaments is limited by the irregularities in diameter which develop after a considerable amount of tungsten has evaporated. These irregularities, after they first appear, tend to magnify themselves very rapidly, on account of the tendency for the current to overheat any spot which becomes thinner than the rest of the filament. The overheating increases the rate of evaporation and rapidly causes failure.

In the gas-filled lamps, however, when helically wound filaments are employed, a new factor is introduced which entirely counteracts this tendency to overheat in spots. In designing the filaments of these lamps, it is evidently desirable to wind the filament on as large a mandrel as possible, in order to obtain the advantage of the large diameter. Since tungsten is a relatively soft material at the operating temperature of these lamps, too large a mandrel should not be used, as otherwise the weight of the filament pulls out the helix very materially in a few hours, and the heat lost by convection may thus become greater than if a helix of smaller diameter had been used. In actual practise the filament is designed so that the amount of sagging during life will be perceptible, but not enough to cause too great a change in the characteristics of the lamp.

If, during the life of the lamp, any part of the filament should, for any reason, evaporate more rapidly than the rest, so that the filament becomes somewhat thinner, this portion will have less mechanical strength than the rest and will therefore sag more rapidly. The helix will therefore open out wherever the filament becomes thin or becomes overheated. This will cause increased heat loss both by convection and radiation, and thus prevent local overheating or spotting.

The use of helically wound filaments increases the life of the lamp many times beyond the life that would be obtained with a straight filament running at the same efficiency. This is especially true of the smaller sizes of wire.

Besides the helically wound filament various other forms have been tried, and, for special purposes, many of these have decided advantages.

DESIGN OF BULBS AND LOCATION OF FILAMENTS.

In the ordinary evacuated lamp, the choice of a suitable bulb is a comparatively simple matter. It must be of convenient size and shape, and provide sufficient room for the proper mounting of the filament. Furthermore, it must have as large an inside surface as possible, so that the density of the deposit of evaporated tungsten will be small. It is also desirable to have the bulb at a sufficient distance from the filament and so related to the power input into the lamp that the bulb does not become overheated. This latter is not only desirable from the viewpoint of safety (in case of lamps for domestic service), but because it is difficult to remove water vapor so thoroughly from the bulbs that the life of the lamps will not be greatly shortened by an overheating of the glass.

In the nitrogen-filled lamps, however, several other factors must be considered, especially in the lamps of high candle-power.

In ordinary lamps about 20 per cent of the energy radiated from the filament is intercepted by the glass and causes heating of the bulb. In the nitrogen lamp, besides this radiated heat, there is an additional amount of heat carried to the bulb by convection—an amount varying with the type of lamp and ranging from 6 to 40 per cent of the total input. The convection currents carrying this relatively large amount of heat travel vertically upward from the filament and strike a relatively small area of the bulb, which thus tends to become greatly overheated. Unless special precautions are taken, this overheating will cause the liberation of enough water vapor to cause attack of the filament and consequent blackening of the bulb. It is thus highly desirable, in ordinary cases, if small bulbs are to be used, that the filament should be placed in the lower part of the bulb. This has the further advantage that it allows sufficient surface of glass in the upper part for the deposition of the tungsten nitride.

For a similar reason it is generally desirable, although not necessary, to make the bulbs with their height considerably greater than their horizontal diameter.

By special design of the bulb, satisfactory lamps have been made with bulbs of only one half to one third as large a volume as that of evacuated lamps of the same wattage. This means that for bulbs of the same volume the nitrogen lamps give roughly from five to ten times the candle-power of evacuated lamps. The bulbs of such lamps naturally run much hotter than those of ordinary lamps. The upper parts of the bulbs are often 100 to 200 deg. Cent. or more, while the lower parts are sometimes much cooler than this, although closer to the filament.

Several special varieties of heat-resistant glass have been used for the bulbs, making considerably smaller ones possible, as well as rendering it easier to get rid of water vapor. Transparent quartz bulbs have been tried, but do not seem to have sufficient advantage over some of the special glasses to offset their present high cost.

LEAD-IN WIRES AND SUPPORTS.

For some of the larger size lamps which take heavy currents (20-30 amperes) it has been necessary to devise special types of lead-in wires. Platinum has been discarded entirely, even in the smaller sizes. Several types of heavy current leads have been successfully used. Most depend on the use of special alloys which have the same coefficient of expansion as the glass. Bulbs of special glasses into which tungsten or molybdenum wire can be sealed directly, have also been used.

In many of the larger lamps the lead-in wires pass through the lower end of the lamp. In this case they can be made short. In others, however, the leads are brought in from the top. This requires more care in the construction of the seal if it is exposed to the heat from the convection currents. Screens are sometimes used to protect the seal or other glass parts from direct contact

*A paper presented at the 286th meeting of the American Institute of Electrical Engineers, New York, October 10th, 1913.

with the convection currents, and to reduce convection.

VARIOUS TYPES OF NITROGEN-FILLED LAMPS.

We have seen that at constant temperature, both the efficiency and the life improve as the diameter of the wire is increased. With very large wires (0.020 to 0.040 inch diameter) which take 20-60 amperes, the efficiency may reach 0.40 watt per candle and probably even better and yet give a life over a thousand hours. It will probably be worth while, in some cases, to use nitrogen in low-current lamps, even if an efficiency no better than that of vacuum lamps is obtained, in order to gain certain other advantages of the nitrogen-filled lamps, such as better color of the light, higher intrinsic brilliancy, etc.

The principal limitation of the new type is therefore that of current. There is no practical upper limit to the current, provided the voltage is not lowered to keep constant power consumption.[1] With increasing current, larger and larger filaments are used and the efficiency that may be practically reached, increases toward the limit of 0.20 watt per candle, which is fixed by the melting-point of tungsten. Unless special expedients are employed, the cooling effect of the leads lowers the efficiency of the lamps by an amount that is inversely proportional to the voltage and nearly independent of the size of the wire or the current strength.

With voltages of 20 volts or more, this effect is not serious, but for voltages as low or lower than 10 volts, it may become very important.

For the particular type of nitrogen-filled lamp which has at present been furthest developed, it may be said that a life of over 1,500 hours is obtained at efficiencies better than 0.50 watt per candle only in large units taking over 10 amperes. Lamps running at 0.6 to 0.7 watt per candle have been made in units taking at least 5 amperes.

No serious difficulty has been met in making high-voltage lamps. In nitrogen at atmospheric pressure there is no tendency toward arcing, even at 250 volts. Many lamps taking 6 or 7 amperes at 110 volts have been made up and run at 0.6 to 0.7 watt per candle, with a life of over 1,000 hours.

A number of special types of nitrogen-filled lamps have been made and tested. Among these the most interesting, for the present, are perhaps the following:

1. *Large Units of Very High Efficiency (0.4 to 0.5 watt per candle with a life of 1,500 hours or more).* These take currents of 20 to 30 amperes and (except in units over 4,000 candle-power) are therefore best run from a-c. circuits by means of small transformers or auto-transformers giving a voltage depending on the size of unit desired. Thus, with 30 volts and 25 amperes, the power would be 750 watts and this, in a lamp of say 0.45 watt per candle, would give 1,670 candle-power. Higher or lower candle-power may be obtained by using other voltages. Typical lamps of this kind are shown in Figs. 1 and 2.

2. *Small Units of Low Voltage.* These take currents of 10 amperes or less and voltages as low as 4 or 5 volts. The efficiencies with 1,000-hour life range from 0.6 to 1.0, or even 1.25 watt per candle, according to the current used.

These lamps are adapted for series street lighting on 6.6-ampere circuits (at 0.6 to 0.7 watt per candle), for stereopticon lamps, automobile headlights and in general wherever a source of high intrinsic brilliancy, steadiness and white color is needed.

3. *Lamps to Run on Standard Lighting Circuits (110 volts).* Large units of this type (several thousand candle-power) have efficiencies of 0.5 watt per candle or better. With smaller units the efficiency is ordinarily not so high.

A lamp of this type is illustrated in Fig. 3. The leads may be brought in from the top, in which case they are preferably made longer so that the filament remains in the lower part of the bulb.

SPECIAL ADVANTAGES OF THE NITROGEN-FILLED LAMPS.

Besides its high efficiency, the features of the new lamps which may, at least for certain purposes, prove of advantage, are:

1. *Color of the Light.* The temperature of the filament being 400 to 600 deg. higher than that of ordinary lamps, causes the light to be of a very much whiter color, so that it comes closer to daylight than any other form of artificial illuminant except the d-c. arc and the special Moore tube containing carbon dioxide. The color is almost exactly like that which can be had for a few minutes by running an ordinary tungsten lamp at double its rated voltage.

Work is at present under way to develop special color screens which, when used with this light, will give a true daylight color (corresponding to the radiation from a black body at 5,000 deg. Cent.). From measurements with the spectrophotometer, it can be calculated that the screens which will accomplish this purpose will absorb from 65 to 75 per cent of the light, so that the net efficiency will be about 2.0 watts per candle for a pure daylight color. At present, to accomplish this purpose with ordinary tungsten lamps, screens must be used which absorb so much light that the net efficiency is between 10 and 12 watts per candle.

[1] As an example, a lamp taking 60 amperes and giving 6,600 candle-power at 0.40 watt per candle has been successfully run.

2. *High Intrinsic Brilliancy of the Filament.* At the operating temperature of the nitrogen-filled lamps the intrinsic brilliancy of the filament is about 1,200 candle-power per square centimeter. In ordinary tungsten lamps, on the other hand, running at about 1.25 watts per candle, the filaments have a brilliancy of only about 150 candle-power per square centimeter. The brilliancy of the filament of the nitrogen lamp is thus about eight times that of the ordinary lamp.

This feature, combined with the high degree of concentration preferably used, renders these lamps particularly useful for projection work, such as for headlights or for stereopticons.

3. *Constancy of Characteristics During Life.* It is often possible to so design these lamps that their ampere-, volt-, candle-power characteristics remain practically fixed during the greater part of their life. In any case, however, since there is no deposit on the bulb to cut off the light, the candle-power practically never falls below 75 per cent (this decrease sometimes being due to sagging). The lamp usually fails by the breakage of the filament with the candle-power well above 80 per cent of its original value.

APPENDIX I.

Light Distribution of Nitrogen-Filled Lamps. In the preceding paper, wherever efficiencies of lamps have been given, they are expressed in watts per horizontal (international) candles measured in the direction perpendicular to the plane of the filament if this is in the form of a single loop.

Careful measurements have shown that with helically wound filaments the distribution of light in a horizontal plane is almost perfectly uniform, therefore the efficiencies that have been given may be considered to represent also watts per mean horizontal candle.

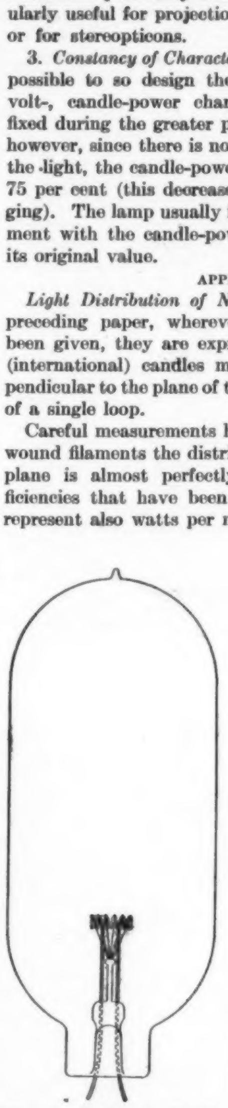


Fig. 3.—Nitrogen-filled lamp for 110-volt circuit.

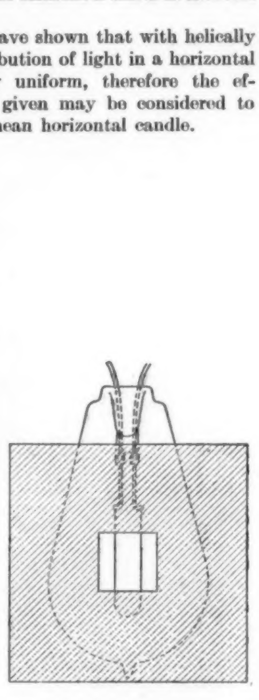


Fig. 4.—Lamp and screen used for calibration of blue glass.

The spherical candle-power of many of the lamps has been measured. The ratio of mean spherical to maximum horizontal (practically mean horizontal also) candle-power has been found to average about 84 per cent for the lamps made with single loops of helically wound wire.

It is possible to design the filaments of nitrogen-filled lamps so as to give a maximum of candle-power in a given direction. This is being done in stereopticon lamps.

APPENDIX II.

Method of Photometry for Nitrogen-Filled Lamps. The usual practice in dealing with incandescent lamps is to determine volts, amperes and candle-power either at a predetermined value of one of these quantities or else at a predetermined efficiency by the "cut and try" method. In the case of a lamp which presents, so many variables as does the nitrogen-filled lamp, however, it is more systematic to regard temperature as the fundamental variable.

The method that has been adopted for these lamps is not essentially novel, although it does not appear to be as well known as it deserved to be.

First: The temperature has been defined by the equation

$$T = \frac{11230}{7.029 - \log H}$$

where T is the absolute temperature and H is the intrinsic brilliancy of the filament in international candle-power per square centimenter (projected area).

Second: A most useful criterion in practice for equality of temperature of tungsten filament is that of color-match.

A little practice with the Lummer-Brodhun photometer enables one to judge equality within 5 deg. if the illumination is good. The most convenient way of setting up temperature standards is to select a number of well-seasoned lamps of high-voltage type in which the anchors are tightly pinched onto the filaments so as to prevent variable cooling effects at the contact. It is best to standardize these, not on a basis of candle-power and filament dimensions, but by the aid of a special lamp and diaphragm as shown in Fig. 4. This lamp is arranged at one end of the photometer with the diaphragm in front of and at a known short distance from it. The filament is preferably stout (say 10-millimeters or 0.025 centimeter) so as to admit of good micrometer measurements.

The diaphragm enables one to disregard the end portions of the filament and select a known length of the part which is at uniform temperature. Of course a simple geometrical correction based on the position of the screen is necessary.

It is thus possible to set up the special lamp at any temperature desired by getting the appropriate candle-power per square centimeter from the filament. The standard lamps are brought to color-match with this arrangement and in this way a set of lamps with known relation between voltage and effective temperature is obtained. The life of the ordinary standard lamps would be very short indeed if they were run at the same temperature as nitrogen-filled lamps. For this work, therefore, the standard cannot be used directly as color-standards. For this reason a most important accessory is introduced in the form of a set of special blue glasses. It is not easy to get a blue screen which will perfectly facilitate color-match of tungsten filaments at different temperatures, but a special blue glass has finally been obtained which answers exceedingly well.

Four distinct screens of different intensity are used, each carefully finished as a uniform plate, and any or all of these may be combined with a tungsten filament run at any temperature and the result will color-match correctly against another tungsten filament at a higher temperature.

It may be shown theoretically and experiment confirms that the following relation holds:

If T is the temperature of a filament which is viewed through screens A, B, C, etc.,

T_1 is the temperature of a filament which matches the above.

Then $\frac{1}{T} - \frac{1}{T_1} = a + b + c$ etc.

where a, b, c, etc. are constants for the screens A, B, C, etc. Thus one only needs to maintain one standard temperature by means of standard lamps and that temperature can be so low that great permanence is insured.

The constants for the four glasses once determined, there are available a number of standard temperatures ranging from 2,250 deg. to 3,600 deg. K.

By the use of these screens it is an easy matter to set a lamp up at a voltage such that the filament has a standard temperature, say 2,850 deg. To do this it is simply necessary to adjust the voltage so that the color of the light from the lamp is the same as that which comes from the standard lamp when viewed through one of the special blue screens.

Since the efficiency in vacuum is very simply related to the color of the light, this method of photometry gives a very simple and direct way of knowing the exact effect which the nitrogen has on the efficiency of the lamp.

Fleas Can Transmit Infectious Diseases

THE flea has already been the object not only of maledictions but also of serious allegations. Like many other insects, it is not content with victimizing human beings, but it must also inoculate them with infectious germs. In a note presented to the Academy of Sciences of Paris, M. Laveran has indicated that all kinds of fleas do not offer the same dangers. The eminent hygienist has, however, signaled most particularly the flagellant flea, which secretes in its intestine a very dangerous parasite. The flagellants also are sometimes to be met with in the dog. It results, from certain experiments made at the Pasteur Institute, by MM. Laveran and Francini, that mice have been infected by injecting into their peritoneum the contents of these parasites diluted in a little physiological water. This had already been remarked in 1912 by Lafont, who had operated with a flagellum from the digestive tube of a bug. M. Laveran has not stated whether men or dogs could be infected by the contact of these fleas, but the effect produced upon the mouse is sufficient to make us uneasy. So let us continue to fight against this troublesome insect and to destroy it everywhere by all the means in our power.—*Chemical News.*

The New Berlin Aquarium

The Old Establishment Resuscitated on a New Site

By Dr. Alfred Gradenwitz

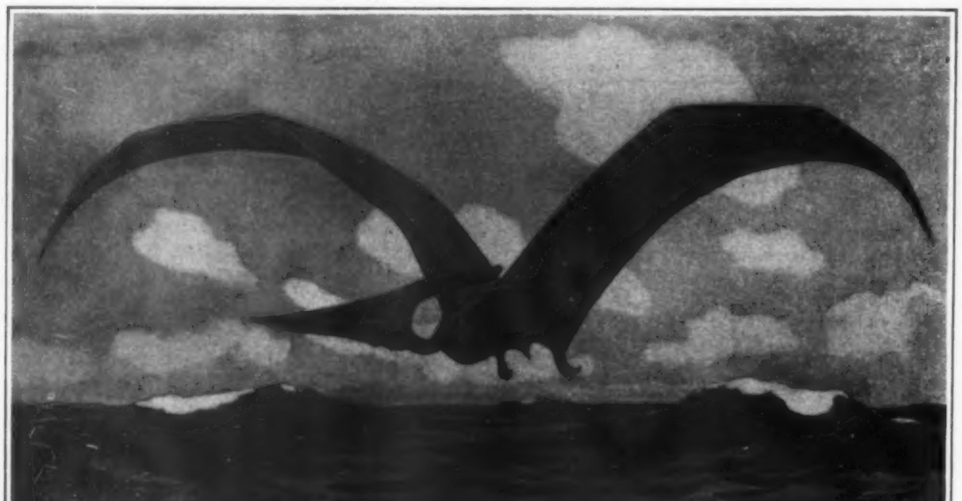
Berlin formerly possessed, among its curiosities, a giant aquarium where aquatic animals were to be found in a motley crowd, side by side with all sorts of birds and monkeys. A visit to this aquarium was invariably included in the programme of sight-seers coming to the Prussian capital, and even those, little interested in zoological studies, considered themselves in duty bound to pay at least a short call to this museum of aquatic life. However, the increasing invasion of the Friedrichstrasse quarter by palatial hotels and office buildings at length obliged the aquarium, nearly three years ago, to close its doors and to part with its varied lodgers.

Dr. Hermes, the founder and for many years director of this aquarium, at once commenced negotiations with the management of the Zoological Gardens, with a view to providing for it a new home on their grounds, that is, at a place where it might be more in harmony with its surroundings and better assured of a prosperous future. At the same time, it was deemed better to define its proper field, by eliminating any non-aquatic animals, though admitting, as uniformly and completely as possible, all cold-blooded vertebrates as well as such invertebrates as could be preserved and exhibited alive. These negotiations were temporarily interrupted by Dr. Hermes' death, but thanks to the active support of the Berlin municipal authorities and the Department of Education, his idea was nevertheless carried out. This is how the new aquarium just opened to the public came into being.

It should be distinctly understood that the magnificent three story building, 175 feet in length and 115 feet in width, rising beside the Elephant Gate at the entrance to the Berlin Zoo, where formerly stood the power house of the gardens, is not merely a gigantic aquarium. The aquarium proper, in fact, only occupies the ground floor; it is taken up in about equal parts by fresh and sea water animals, housed in 25 huge tanks each 8 feet in length and in 50 smaller tanks. The sea water was brought from the North Sea and is said to have constituted the largest salt water cargo ever carried by a vessel. On the first floor there is the terrarium, where reptiles and amphibians are kept in 19 large and about 60 smaller tanks. The whole of the huge glass-roofed central hall (56 feet in length and 33 feet in width), however, has been converted into a grand panorama, representing a half dried out stream in the tropics, with its luxurious vegetation, where crocodiles are seen lying on the river sand, while water turtles lustily swim in the water pools. This panorama, which is unique in its kind, is reached across a bamboo bridge and forms the chief attraction for the bulk of the public. On the second floor there is finally an immense insectarium, where the ways of the insect world are illustrated, in as lifelike a fashion as possible, in a long series of insect cages.

A relatively modest wing contains the offices, employees' dwellings and scientific laboratories, amply provided with aquaria and terraria. In the basement of the main building there are the pumps and settling tanks for fresh and sea water. The big water tower connected with the building contains for fresh and salt water respectively reservoirs feeding the various tanks.

The Berlin Zoological Gardens hitherto contained only mammals and birds, though in numbers equaled by few other institutions of this kind (about 1,400 different species). Thanks to the aquarium recently inaugurated, its collections now embrace the whole of animal life, with a wonderful abundance of species. However, the aquarium teaches a vivid lesson in biology, not only by the exhibition of so many representatives of aquatic animals, but also by the very architecture and ornamentation of the building; every free surface on its façade and walls has been utilized to complete the scientific instruction received on going through its collections. Thus the prehistoric cousins of the present inhabitants of the aquarium are represented by pictures and plastic models based on the remnants found in the triassic and jurassic strata. All the principal types of gigantic reptiles known as saurians are there exhibited, the most striking representative of this collection being an iguanodon, 16 feet high, enthroned in life size in front of the building, on a rocky base beside the large bridge crossing the water tank outside the aquarium. In addition to these reconstructions, in which fancy, of course, plays a certain part, there are also real fossils on exhibition, among them an excellently preserved ichthyosaurus.



Mural painting on the street façade. Pteranodon in flight.

Sea anemones and other aquatic forms of life.

The Evolution of the Modern Stereoscope*

Many Forms of the Instrument Have Been Devised

By A. Lockett

The valuable aid offered by the stereoscope to the scientific investigator is again attracting notice. In astronomy, photo-surveying, the surgical applications of radiography, photo-micrography, the treatment of certain diseases of the eyes, and in many other new and often unexpected ways, stereoscopy places a fresh power in the hands both of the inquirer and the expert. Even the cinematograph is now made to give moving pictures in natural relief—a development opening out a wide vista of possibilities.

The stereoscope itself has been greatly improved of late years, and a better understanding of the principles on which it depends has led to the production of new models embodying important modifications. This being so, the time seems not inopportune for a brief sketch of the modern evolution of stereoscopic apparatus and some consideration of those factors that have to be studied in order to secure the maximum satisfaction of optical and physiological requirements. Clearly what is needed is the best practical performance, together with the greatest possible convenience and the least complication. These different qualities may not be obtainable together, but that will evidently be the most perfect

* Reproduced from *Knowledge*.

instrument which enables the truest balance to be struck between them.

Like telescopes, most stereoscopes may be divided into two classes, those, namely, that utilize reflection and those depending upon refraction. A third class which relies upon neither, but includes several instruments or systems of unique character, may, perhaps, most conveniently be considered first.

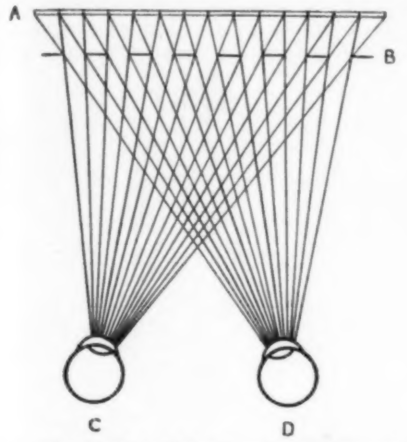


Fig. 1.—The principle of Ives' parallax stereograph.

The earliest stereoscope, Elliott's—designed in 1834, though not constructed till 1839—dispensed with all optical intervention, the two pictures, or rather diagrams—for photography was then non-existent—being viewed direct by the observer. The instrument thus possessed two excellent features; but, unfortunately, it was necessary to cross the axes of the eyes in a somewhat unnatural manner, which called, in many cases, for a little troublesome practice before it could be accomplished.

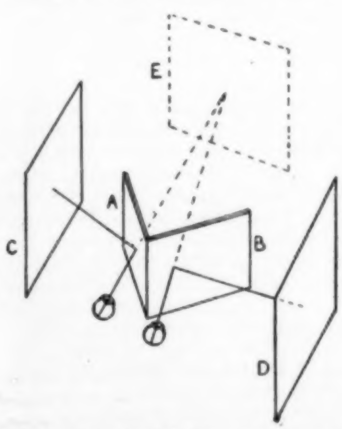


Fig. 4.—The principle of Wheatstone's reflecting stereoscope.

On that account Elliott's stereoscope never came into general use.

A modified form of the Elliott instrument, devised by the writer in 1912, may be of interest. As shown by Fig. 11, it consists of a tapering box, *A*, having two oval openings at the front for the observer's eyes and a rectangular opening at the back. In the diagram the top is removed for clearness of illustration. The box is blackened inside, and to the bottom is attached a narrow piece, *B*, on which slides a holder similar to those used on the ordinary American stereoscopes. The two photographs must not, as is usual, be transposed in mounting, but should be allowed to remain just as they are printed from the negative, the picture for the right eye being on the left and that for the left eye on the right. To use the apparatus it is held by the handle, *D*, and the stereograph is moved to and fro, keeping one eye shut, until one picture appears to fill up the aperture in the back. On opening the other eye the combined images will then usually be seen in stereoscopic relief, or, if not, a few further trials will ensure this result. The principle involved is obvious. Owing to the fact that nothing can be seen except through the back opening, placed midway between the two pictures, the right eye can only perceive the left-hand picture, while the left eye beholds only the right-hand one. At the same time they are both mentally referred to an apparently identical position, so that they coalesce and give the effect of natural relief.

For a reason to be explained later, another unique method, the parallax system of F. E. Ives, though of much later date (1903), may not inappropriately be dealt with next. By this highly ingenious method each stereograph carries its own viewing arrangement, so that no separate instrument is required. In making the negative, the two slightly different images are superposed on each other. This may be done in various ways, but that commonly adopted is to use on the camera a single plano-convex lens of about three inches diameter, placing behind this a diaphragm having two small openings two and a half inches apart. A screen ruled with fine vertical lines, about one hundred to the inch, is interposed between the lens and the plate at such a distance from the latter that it splits the two

Fig. 2.—A diagram illustrating analogy between Ives' system and Elliott's instrument.

images into a series of adjacent lines, every alternate line consisting of a portion of one image only, while the intermediate lines represent parts of the other image. From the resulting negative, a transparency is made and is bound up with a line screen of the same spacing as that with which the photograph was taken, kept at a similar distance by a cardboard mask. On holding the bound-up transparency at the correct distance from the eyes, usually about twelve inches, perfect and beautiful

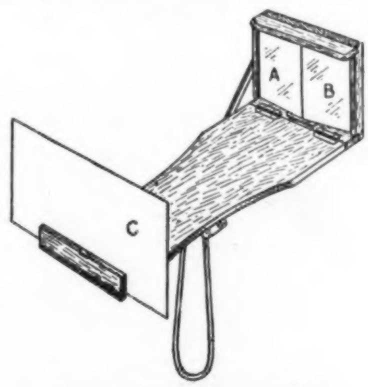


Fig. 5.—The "reflectascope."

stereoscopic relief is perceived. Fig. 1 illustrates, on a much enlarged scale, the precise action of the ruled viewing screen, *A* being the transparency, *B* the screen, and *C* and *D* the eyes of the observer. It is obvious that either eye sees only the intermediate portions forming its own proper picture, while the two pictures are at the same time superposed and united. For the best result, the opaque lines of the taking screen should be twice the width of the transparent interspaces, as this prevents the parallax lines from running into each other when developed.

If we consider any two adjacent spaces of the composite transparency in relation to a single opening in the line screen, as shown by Fig. 2, the remarkable similarity in principle to Elliott's early apparatus will be evident. The Ives stereograph consists, in fact, of

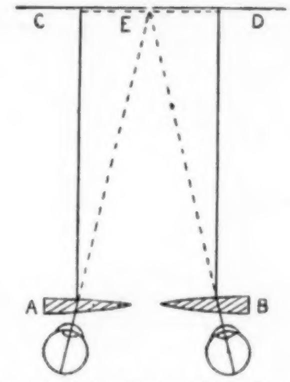


Fig. 3.—The principle of Brewster's refracting stereoscope.

hundreds of tiny Elliott stereoscopes, all inspected simultaneously. While the results obtained are unexceptionable, there are two obstacles to the general adoption of this system. One is the necessity of precise adjustment of the distance of the ruled screen from the plate in relation to the camera extension and the separation of the two viewpoints, besides the corresponding care required in binding up the positive, the other being the fact that only transparencies can be made.

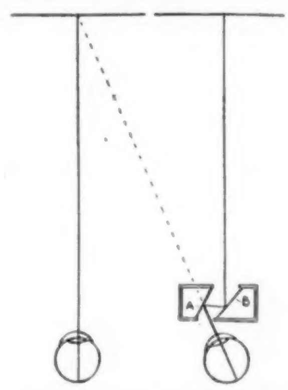


Fig. 6.—Theodore Brown's pocket reflecting stereoscope.

Yet a third method of stereoscopy, utilizing neither reflection nor refraction, is the anaglyph system of Louis Ducos du Hauron (1890) in which the two pictures forming the stereograph are printed, one over the other, in red and blue ink respectively. The resulting jumbled combination is viewed through spectacles containing a red and a blue glass, or similarly tinted pieces of gelatine.

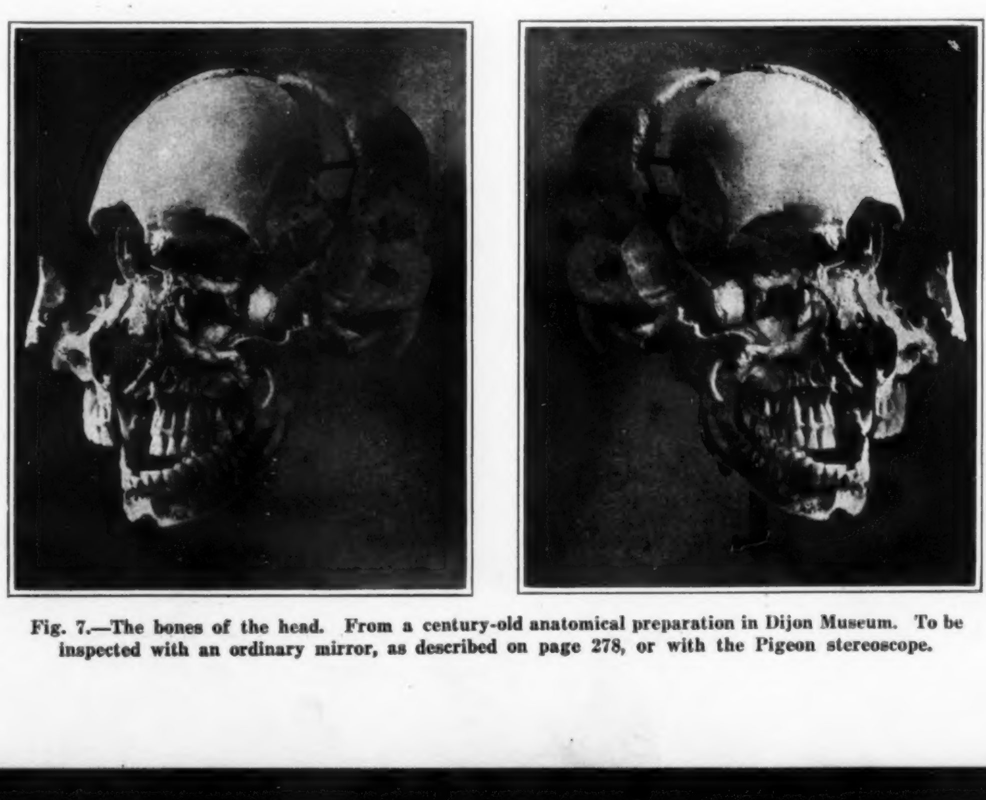


Fig. 7.—The bones of the head. From a century-old anatomical preparation in Dijon Museum. To be inspected with an ordinary mirror, as described on page 278, or with the Pigeon stereoscope.

Through the red glass, the red image is invisible and the green one appears black, while through the green glass the reverse is the case. As each eye, therefore, sees only its particular picture, and the two are superposed, stereoscopic vision results. Prints of any size may be produced and viewed in this way, and the stereographs evidently occupy only half the space that would be necessary if the two pictures were placed side by side in the usual manner. The drawbacks are a considerable loss of light from the presence of the color filters, and the fact that the prints cannot be inspected without the viewing arrangement, as is often desired. Though Du

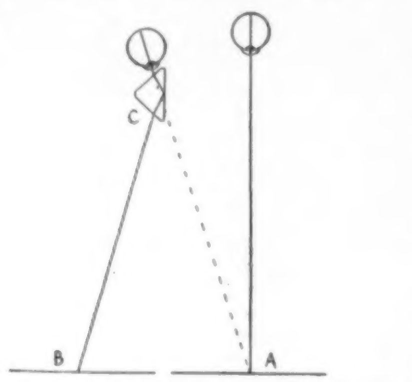


Fig. 8.—The principle of Pigeon's prism stereoscope.

Hauron was undoubtedly the first to employ the foregoing method with printed stereographs, it should be stated that the principle was foreshadowed by Dove in 1843, and by Rollmann in 1853, while D'Almeida, in 1857, used a very similar system, but with red and green glasses for stereoscopic projection by the lantern.

Turning now to refracting stereoscopes, that of Sir David Brewster, familiar as the old box-form pattern of early Victorian days, comes first in order. Initially studied by its inventor in 1844, and communicated to the British Association in 1849, this instrument was not placed on the market till 1851, when Duboscq, of Paris, undertook its manufacture. The principle of Brewster's stereoscope is probably so well known that explanation is almost superfluous. A few words, however, may be desirable. The lenses of prisms *A* and *B* (Fig. 3), cut from the two halves of a bi-convex lens and turned with their thin edges inward, so refract the rays from the two pictures *C* and *D* that the eyes of the observer see them converged together, both images being superposed at *E*. Since, nevertheless, each eye sees only its own proper half of the stereograph, the result is stereoscopic relief. A more convenient form of Brewster's instrument, designed by Oliver Wendell Holmes in 1861, with the further improvement of a sliding view-holder, added by J. L. Bates in 1864, is now in general use.

The refracting stereoscope has the advantages that no light is lost and that the image is magnified. Counterbalancing these merits are the facts that in magnifying the prints the grain of the paper is also enlarged, detracting from the fineness of the image; that only pictures of a small and rather awkward size can be employed; that the instrument has to be focused to suit differences of vision; and, finally, that a slight degree of distortion, if not of other optical aberrations, is present. It may also be added that some observers have difficulty in combining the two images with this type of apparatus.

Variations of Brewster's instrument have been numerous. Whole lenses have, for instance, been used, as in the telescopic stereoscope of De la Blanchère, which resembled a pair of opera glasses with the two tubes adjustable as to convergence. It is not, by the way, generally known that if we look through an ordinary opera-glass pointed wrong way round at a stereoscopic slide, a single small image in relief will be seen. Another interesting stereoscope, devised by Steinhauser, had lenses contrary to those of Brewster's apparatus, causing the optic axes to cross, so that untransposed stereographs could be utilized. The chief modern improvements on Brewster's instrument, apart from the American hood and sliding holder, have been the employment of achromatic instead of single lenses, and provision for altering the separation between them to suit the distance between the eyes of any observer. Such refinements, however, are still only met with in the higher-priced lenticular stereoscopes.

In the opinion of many, the reflecting principle offers the fewest disadvantages, now that its earlier constructional drawbacks have been overcome. It is not without interest to trace the evolution of the reflecting stereoscope, from the cumbrousness and complexity which at first distinguished it, to its latest developments and refinements. The earliest stereoscopic apparatus making use of reflection was invented by Sir Charles Wheatstone in 1838—next in order, therefore, to Elliott's apparatus. As shown by Fig. 4, it had two plane mirrors, *A* and *B*, inclined together at an angle of 90 degrees, silvered side outward, the two pictures *C* and *D* composing the stereograph being placed one at each side, and the observer viewing their images in the mirrors. As both images were reflected into an identical position at *E*, and thereby made to coalesce, while, at the same time, each eye saw only its own particular picture, stereoscopic vision resulted. The chief drawbacks of this arrangement were that the two pictures had to be inserted separately; that, if any adjustment were needed, both pictures had to be advanced toward or withdrawn from the mirrors simultaneously, which involved the use of a clumsy double-threaded screw; that the reflected image was necessarily reversed as regards right and left; and that the efficient lighting of both pictures, from two contrary directions, presented serious difficulties. This instrument was therefore soon superseded. It may be remarked that, besides claiming credit for the inception of the first reflecting stereoscope, strong ground exists for believing that Wheatstone was aware of the principle of—if he had not actually constructed—the lenticular form prior even to Brewster.

There have been many variants on Wheatstone's instrument, since it is obvious that the two prints and mirrors may be arranged in numerous different ways. One of these, known as the reflectascope, is illustrated by Fig. 5. As will be noticed, two plane mirrors are placed at *A* and *B*, joining at a very obtuse angle. The stereoscopic slide, the back only of which is seen in the figure, is inserted in a holder at *C*, and the observer, looking over the slide, sees in the mirrors a single picture in relief. The chief drawback here is that the join between the mirrors shows, though almost imperceptibly, as a thin line across the center of the combined image. If the two mirrors are inclined inwards away from the slide, instead of outwards, the arrangement otherwise remaining the same, non-transposed stereoscopic slides may be used. In both cases the image is reversed as regards right and left.

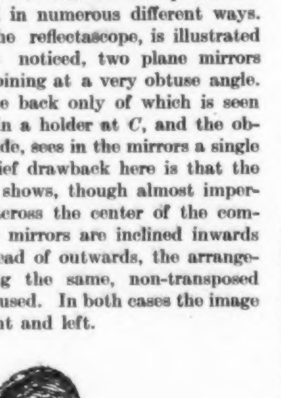


Fig. 10.—The method of inspecting Pigeon stereographs with an ordinary plane mirror.

It is an evident advantage that optical aids should be dispensed with so far as possible, in order that the eyes view the stereograph direct. Except in Elliott's instrument, the drawbacks of which have been pointed out, this desideratum is incapable of practical fulfilment. There are, however, several systems in which one eye at least regards its own picture direct. Various suggestions to that effect were made, at different times, by H. W. Dove, Brewster, and Rollmann; but, as a modern instance of efficient performance combined with convenience, Theodore Brown's tiny pocket stereoscope (1895), doubtless the smallest made, may be mentioned. In this, as shown by Fig. 6, two small mirrors, *A* and *B*, are enclosed in a case, nearly but not quite parallel with each other. Looking through an aperture in the case, the right eye views its proper picture by double reflection, apparently superposed on the left-hand picture, the latter being seen direct by the left eye. The same idea is obviously applicable to a double reflection prism having sides of suitable angle.

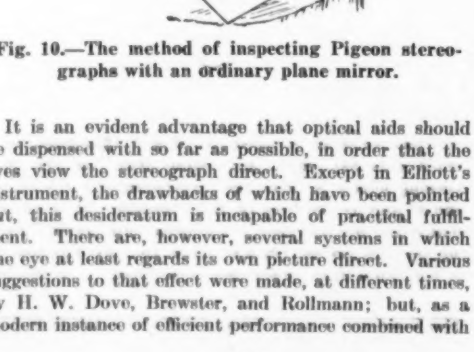


Fig. 11.—Modified Elliott stereoscope.

Mirrors, to give optically perfect results, should be surface-silvered, but are then unfortunately liable to

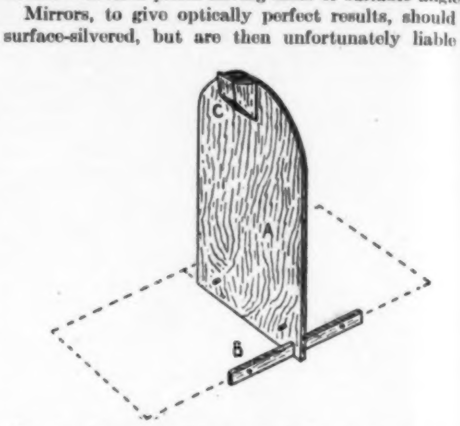


Fig. 9.—The constructive details of Pigeon's prism stereoscope.

tarnish, and are very susceptible to injury by moisture, scratches, or abrasion. Reflecting prisms serve all the purposes of mirrors and are free from these disadvantages, besides being more easily cleaned. Many prismatic stereoscopes have been constructed, among which may be recorded that of Girard-Teulon (1861), in which four total reflection prisms were used, and several forms of apparatus invented by Sir Howard Grubb (1878), in which the two stereographic prints were mounted one above the other, instead of side by side. In another instrument by Grubb the two pictures of an ordinary stereoscopic transparency were thrown in superposition on to a concave mirror by means of a combination of prisms and lenses, the observer, at a suitable distance, seeing an aerial image in relief. It may be mentioned that Duboscq and also Jequezel, both in 1857, made stereoscopes having prisms as well as lenses, so that both reflection and refraction were employed. These instruments were, however, practically modifications of Brewster's apparatus.

Whether mirrors or prisms are used, it is fairly evident that a double reflection must involve more loss of light, and must require a more exact adjustment than a single one. There is therefore a special advantage in the prism stereoscope invented by Professor Léon Pigeon, of Dijon (1910), who is also known as the contriver of the compact and useful book-form mirror stereoscope named the "Dixio" (1905). In Professor Pigeon's prism stereoscope (see Fig. 8) the right-hand picture, *A*, is viewed direct, while the left-hand one, *B*, is seen by a single reflection in the prism, *C*, apparently superposed on *A*. It is necessary that the left-hand print should be laterally reversed, a condition easily fulfilled, among other obvious ways, by making the prints in carbon, one by single and the other by double transfer; or, if film negatives are used, by printing the left-hand picture from the back. As shown by Fig. 9, the apparatus consists of an upright panel, *A*, supported by a narrow cross-piece, *B*, the prism being mounted in a hood, *C*, which screens stray light from the left eye. The prints, which may be of quite large size if desired, are laid flat on a table and the instrument is placed over the central line between the two pictures, as indicated. Large prints may conveniently be hinged together by a tape glued across the back at the junction, in order that they may be kept unmixed and may fold up when not in use. For prints over 8-in. +6-inches the stereoscope should be raised in the hand, so that a longer viewing distance is obtained. Besides its ordinary purpose the model illustrated is very suitable for viewing stereoscopic illustrations in books. Another pattern, it may be stated, makes provision for the inspection of transparencies and autochromes. On the whole, the Pigeon stereoscope—the last word, so far, in reflecting instruments—certainly seems to offer a maximum of efficiency, combined with extreme simplicity. The image is exceedingly clear and brilliant, while with a front lighting absolute uniformity of illumination is easily secured. Those who would like to have ocular demonstration of the principle involved may readily do so by using an ordinary plane mirror, about eight inches or ten inches high, supporting it in a vertical position on the line between the two prints, the silvered surface being to the left, as shown by Fig. 10. For the purpose of experiment an admirable anatomical study from an exhibit in Dijon Museum, taken by M. L. Chapuis in collaboration with Professor Pigeon, and

reproduced by kind permission of the latter, will be found illustrated by two pictures on page 278. The effect with an ordinary mirror will not, of course, be so good as with a surface-silvered one, but will still enable an excellent idea to be obtained of the results possible.

It may be mentioned that an ophthalmological stereoscope on the reflecting principle has been invented by Professor Pigeon, for the diagnosis and treatment of strabismus, or squinting. Besides its primary use, it may be employed for the direct study of the problems of binocular vision; for investigations concerning the function of the motor muscles of the eye and paralysis of these muscles; for the physiological fusion of color; for the medico-legal examination of alterations in sight, real or simulated; and for many other purposes.

In conclusion, some remarks concerning the relative merits of small and of large stereographs will not be irrelevant. It has been stated by several writers that a small print inspected at a short focal distance gives really the same stereoscopic effect as a larger print viewed from a greater distance. To a certain extent this is true; but there is a grave fallacy in the reasoning, since the much greater amount of detail secured in the larger picture is overlooked. To make the matter plainer, compare the case of an enlargement made from a small negative with that of a large direct photograph the same size as the enlargement. There can be no question as to which of the two will give the more detail. The large direct print will show many things that are not visible in the enlargement, it being, therefore, clear that they are absent in the small picture. Large prints, moreover, are seen with less fatigue, make a more definite impression, need no objectionable magnification, may be made with lenses of a more acceptable focal length, and are more useful for purposes of investigation or for the deduction of measurements.

The Puma-Jaguar Controversy

The Problem of the Geographical Distribution of Two Species

By Lincoln Wilbar

In studying the habits of wild creatures, it is sometimes possible to explain vexed or obscure points by referring them to recognized analogies between wild and domesticated animals. Great care, of course, must be exercised that these analogies are not pushed too far, for the hiatus between the domestic animal and its wild congener, while it has not yet obliterated all traces of common fundamental traits, none the less has effected subversive changes, and unless these are taken fully into account, any reasoning based on a putative analogy between the tamed and the untamed of a genus is likely to prove to be faulty.

Especially must attention be given to the constancy of the genus and of its sub-divisions. Some species show great stability of custom, even under considerable compulsion of environment and conditions. Others fluctuate almost beyond the point of recognition, while still others change with astonishing facility and abruptness in those matters of local habit which we group comprehensively under the head of "adaptability," but carry certain racial traits with singular fidelity through every age and the contrasting vicissitudes of their lives.

Of these latter species, those which constitute the Felidae are, perhaps, as retentive of dormant primigenous instincts as they are susceptible of infinite variations of those qualities which are actively concerned in the fight for survival. Save in such attributes as have been influenced by the recurrent incidents of their daily lives, therefore, I should expect to find these species much the same to-day as they were in the beginning, no matter what the character of their environment may have been in the intervening centuries.

This being accepted as provisionally true, I am tempted to explain a puzzling contradiction in the puma's character and procedure by comparison with the conduct of the ordinary house cat in analogous circumstances. The principle is what may be called the moral dynamics of the home instinct; the application, the vexed question of the relative courage of puma and jaguar.

Between these animals, as every sportsman-naturalist knows, there exists a rivalry for supremacy. And this rivalry is characterized, as to its results, not by the usual more or less uniform dominancy of one species over another, as would be the case on a basis of physical superiority, but by topographical differences, the dominant species in one area being the subject species in some other.

That this variation is not attributable, in any appreciable degree, to subversive changes in the dispositions of the animals, or to mere local conditions, is certain; and as no other explanation has been forthcoming, writers on this most interesting but perplexing subject have fallen into two groups—those who support the pretensions of the puma, and those whose arguments are no less emphatic in favor of the jaguar. The latter group is perhaps unduly influenced by conditions as they exist north of the Isthmus of Panama; the former, and much the smaller, group being equally dominated by conditions peculiar to the southern continent.

Of the merits of either case it is not necessary to express an elaborate opinion here. Both are right to a certain point, both are wrong when they pass beyond it; their fault is the fault which exists in all inelastic conclusions reached, without due allowances being made, from antagonistic premises. Suffice it to say, therefore, that whatever doubt may have dwelt originally in the minds of naturalists and sportsmen as to the relative positions of puma and jaguar, there can be no question that the adjustment of the rivalry between these animals is a matter of a more or less local character; and as the principle governing the adjustment is certainly not the active one of tooth and claw, it is at least permissible to presume that the passive force which I have described as the dynamics of the home instinct is the determining factor in this adjustment.

The power of the sense of being at home is common to all animals, as to human beings; but because what I may term the submerged instincts of *Felis domestica* are identical with those of the wild Felidae, I select the house-cat as the most suitable illustration of my meaning.

Everyone has noticed the apologetic difference of a cat introduced into the home surroundings of another, and has doubtless smiled at the exaggerated moral importance of the latter. When the interloper is noticeably the smaller of the two, the adjustment of their relative positions is, of course, along purely physical lines; while if the opposite is the case, physical values reassert themselves as soon as the balancing influence of the home feeling is weakened by association; but when both cats are about evenly matched n size, strength and courage, the moral advantage of previous possession passes naturally into settled authority, and so long as they are together, no matter how friendly their relations may become, they retain the original mutual attitude of lord and vassal.

Now, since in a wild state all instincts are greatly exaggerated, it is reasonable to suppose that the descendants of two animals like the puma and the jaguar, nearly related members of the same genus, would preserve the relative positions of their progenitors, so long as they remained in the same district. If, therefore, we presume that at some early date pumas and jaguars occupied separate areas, and that as time went on each species trespassed on the domain of the other (as undoubtedly did happen in certain parts of South America), we have a satisfactory solution of a most perplexing problem—one that cannot be solved by reference to the usual arbiters of the wild, superior strength and courage.

To collect and collate data bearing on this subject, to cover practically every region of the puma's habitat from its southernmost range in Patagonia to its septentrional limits at about lat. 51, and to make equally exhaustive inquiry into the geographical distribution, habits and temperament of the jaguar, both as they are known to-day and as they were represented to be, back to that point of time when travelers' tales began to give place to more reliable information, has not been easy, nor has the work been entirely satisfactory, owing to the difficulty of obtaining really trustworthy facts; but after a fashion the labor of love has been performed.

The result is a mass of material (much of it necessarily derived from Spanish sources of questionable value), a preliminary survey of which, from any other point of view than that of the hypothesis in question, might easily support the arguments of either group of theorists; but as the work of sifting and classification went forward, the significance of geographical differences became obtrusive, and unless I have been led away by an idea into erroneous reasoning, as Bacon says mankind is prone to be, the facts of the original distribution of the two species, and the variable attitude assumed by each toward the other, justify the assumption that the relative position of either species in a given area is not a matter of individual or class superiority (except in sporadic cases), but was determined by the same force that adjusts the domestic relations of house-cats in the circumstances set forth above.

There are, of course, several arguments against this theory, as there are arguments against every theory. But they pertain, it seems to me, to exceptions, and I feel sure that were it possible at this late date to give a comprehensive and authoritative account of all the facts relating to the early distribution of the two species, their subsequent movements and the changes effected thereby in the habits of the animals, such an account would go far toward clearing up the puma-jaguar controversy.

Unfortunately, however, we do not know, and never can know definitively, what the original scheme of distribution of the two species was in those parts where even our most remote traditions give them common occupancy. Prior to the brief period of fairly accurate knowledge, therefore, everything must be unprofitable guess-work, no matter in what erudite form the guess may be cast. We can judge of the whole only from what has actually happened within comparatively recent years in certain localities lying just outside of what we define as the limits of the jaguar's natural range.

As is well known, the jaguar has a much more restricted and central habitat than the puma, and within the area which may be regarded as its home it rules supreme over its cousin *Felis concolor*, whose natural habitat appears to have lain originally to either side of this central domain of the jaguar. As the species increased in numbers, however, expansion necessarily took place, the puma living on sufferance in the territory of the jaguar, the jaguar passing over into the country held by the puma. So far as I have been able to ascertain, the movements of the jaguar were almost entirely southward, the northern limits of its habitat remaining practically unchanged, and to this fact I attribute the supremacy of the jaguar over the puma in the country north of the Isthmus of Panama.

Southward, conditions were somewhat different. There can be no question that in those regions the jaguar far over-traveled its original boundaries, trespassing on the natural home of the puma, and it is in those regions that we find the puma the dominant species. This total change of attitude may, of course, be due to several other causes, but it is at least significant that the change should correspond so closely with the changes of habitat and the consequent change in the moral effect of the home feeling. Failing this explanation, how are we to account for the singular spectacle of a species that is unquestionably lord and master so long as it remains within its own territory, but which becomes subservient to another closely related species when it trespasses on the domain of the latter?

Area of Earth's Surface Visible at Any Altitude

Mr. W. Moss, writing in *Nature*, says:

"In these days of aviators and of record heights attained by them, perhaps the following rule to find the area of the earth's surface visible from a given height may be of interest. The rule depends upon the fact that if the height above a sphere is $\frac{1}{x}$th part of the sphere's diameter, then the area visible from this height is $\frac{1}{x+2}$th part of the sphere's total area. This admits of an easy geometrical proof.

"*Rule.*—Express the height above the earth's surface as a fraction of the earth's diameter; multiply the numerator of this fraction by 2, and add the result to the denominator, then the resulting fraction gives the fraction of the earth's surface visible.

EXAMPLES

Height Above Earth's Surface.	Height Expressed as a Fraction of Earth's Diameter.	Fraction of Earth's Tota Surface Visible.
24,000 miles..............	$\frac{3}{1}$	$\frac{3}{7}$
8,000 miles..............	$\frac{1}{1}$	$\frac{1}{3}$
70 miles..............	$\frac{7}{800}$	$\frac{7}{814}$
1 mile..............	$\frac{1}{8000}$	$\frac{1}{8002}$
506.881 inches..............	$\frac{1}{999998}$	$\frac{1}{10^6}$
42.24 feet..............	$\frac{1}{10^6}$	$\frac{1}{10^6+2}$
At the moon (240,000 miles)	$\frac{30}{1}$	$\frac{30}{61}$

"Of course, the effects of refraction are neglected; otherwise the rule is strictly accurate."

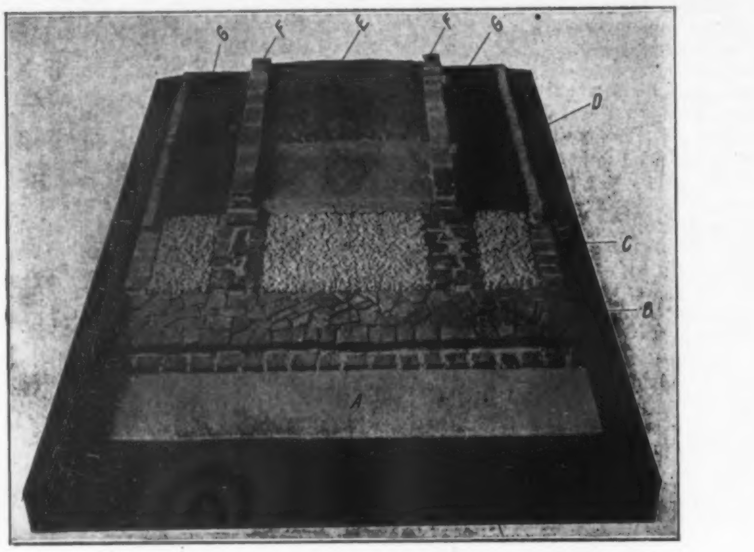


Fig. 1.—Model showing the construction of the Appian Way (300 B. C.).

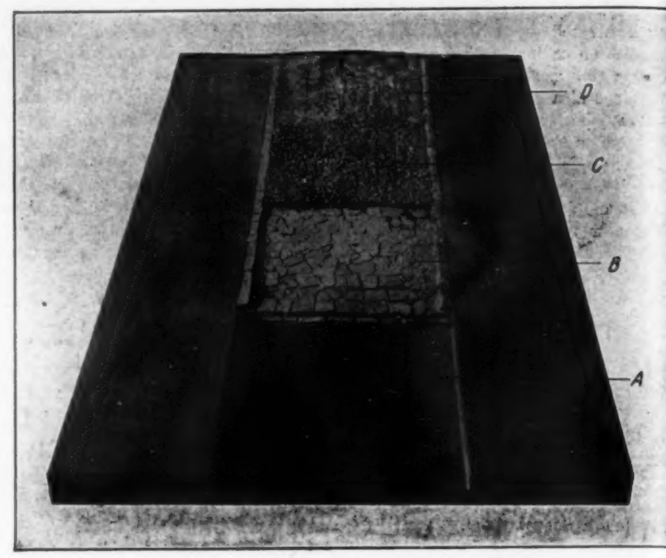


Fig. 2.—Model showing a French road built before 1775 (Roman method).

Road Models of the Office of Public Roads*

From Roman Times to the Present Day

ROMAN ROADS.

The Romans began building roads on a large scale more than 300 years before the Christian era. The Appian Way, one of the most celebrated of their roads, was begun in 213 B. C., by Appius Claudius Cæcus. This road led from Rome to Capua, a distance of 142 Italian miles. It was later continued to Brindisi, making the total distance 360 miles. Rome continued as a great road-building nation for about 600 years, and some of its roads remain in part to the present time. The Appian Way is said to have been in perfect condition more than 800 years after its construction.

The Roman construction was often varied, though always extremely massive. The general form of construction employed during the reign of Cæsar Augustus, when Roman road building seems to have reached its height, was a massive road from 16 to 30 feet wide, 3 to 4 feet thick, and laid in three or four courses. The first course was almost invariably of large, flat, field or quarry stones laid on earth, except in swamps, where poles, logs, brush, or even boards were used beneath the stone course. The other courses varied extremely with the available material and the period and importance of the road. Small stone with and without mortar, gravel mixed with clay, broken brick, tiles, etc., and even earth was used for the second and third courses. The surface or wearing course consisted of well-cut, irregular, close-fitting polygonal blocks on a few of the more important roads, but more often it consisted of uncut stones, not unlike our cobblestone pavements, or of gravel, and in some cases of a mixture of sand and clay or clay and gravel.

Fig. 1 shows a model of the Appian Way. This is the most highly developed type of road constructed by the Romans.

Section A shows the contignatum pavimentum, composed of lime and sand, straw, rushes, or reeds, and sometimes laid on sills or boards.

Section B shows the statumen, or foundation, composed of two courses of flat stones laid dry or in lime mortar. This course was from 16 to 18 inches deep.

Section C shows the rudus, or rubble, composed of broken stone mixed with lime in the proportion of 1 part of lime to 3 parts of stone. Sometimes the material was taken from old buildings. This course was laid from 6 to 9 inches deep.

Section D represents the nucleus, composed of coarse gravel and lime used hot, or bricks, potsherds, or broken tile mixed with lime and covered with a thin layer of lime mortar.

Section E shows the summa crusta or pavimentum, consisting of polygonal blocks joined with the greatest nicety. This course was about 6 inches deep and about 16 feet wide.

Section F indicates the curbs, which were 2 feet wide and 18 inches high, with upping blocks as shown in the illustration. These blocks served as seats for travelers and as mounting blocks for riders.

Section G shows a side road, the surface of which was composed of gravel flushed with mortar. The width was from 6 to 8 feet.

FRENCH ROADS.

From the viewpoint of construction, road building in France may be divided into three periods—the period of Roman influence, the period of Trésaguet, and the modern period.

By the time that road building was revived in France in the seventeenth century the Roman methods of road building had been greatly modified, though the Roman form, especially in the foundation, was still retained. Under the ministry of Colbert (1660-1669) as controller general of finances, about 15,000 miles of stone roads were built, practically all with an undrained foundation consisting of one or more layers of large flat stones placed in the bottom of a trench-like excavation. These stones were then covered with a thick layer of more or less finely broken stone. As no systematic maintenance was attempted, the roads rutted badly, and it was only rarely that the broken stone consolidated properly. The total thickness of the roads was from 1½ to 2½ feet.

About 1775 a form of construction, supplemented by continual maintenance, came into prominence in France. It had long been advocated by Pierre-Marie-Jérôme Trésaguet, a noted French engineer. He held that good drainage and systematic maintenance were absolutely necessary to have good roads. By providing a properly crowned and drained foundation, he reduced the required thickness more than one half and provided a better and more serviceable road. The small stones were broken more uniformly and, by a little attention after placing, soon bonded under the traffic. The roads became smooth and afforded comfortable traveling.

By 1830 most of the great highways of France had been completed. The roads remaining to be improved were largely of the secondary class. For such roads the Macadam method was adopted almost exclusively. At the present time road building in France is confined largely to the "vicinal" and rural roads and to the necessary reconstruction and maintenance of the roads already built.

FRENCH CONSTRUCTION PREVIOUS TO 1775 (ROMAN METHOD).

Fig. 2 illustrates the type of road constructed in

* From Bulletin 47 of the Office of Public Roads, Department of Agriculture.

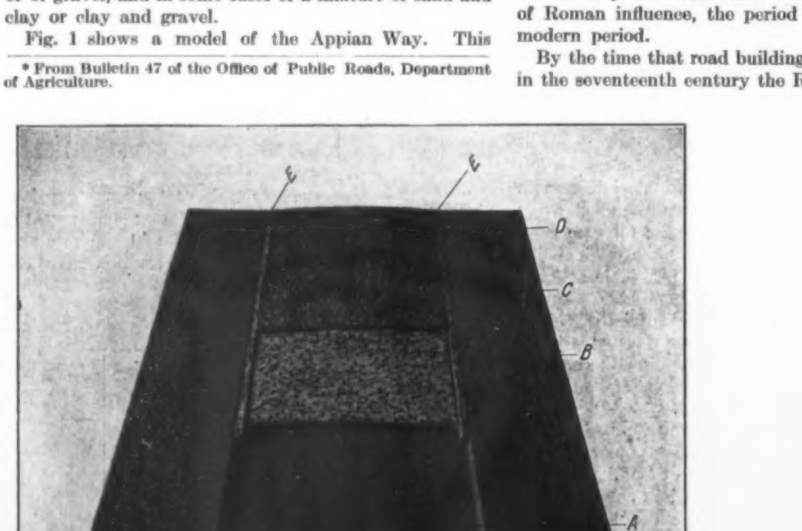


Fig. 3.—Model showing a French road of Trésaguet, built between 1775 and 1830.

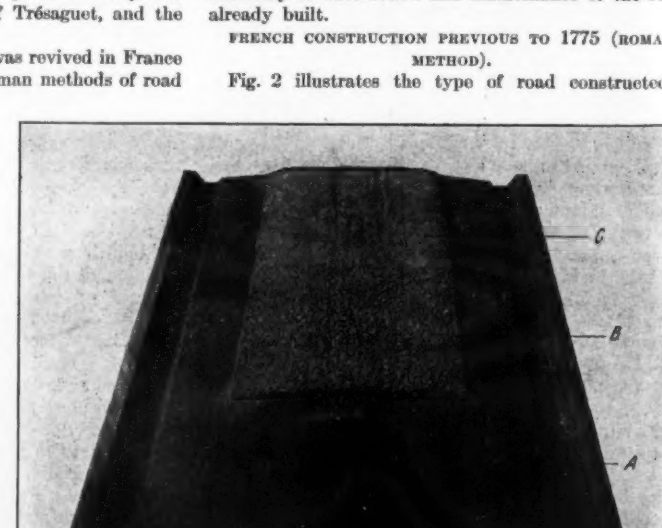


Fig. 4.—Model showing a Macadam road of the type built by Macadam (1816).

France previous to 1775. This type was modeled on the Roman system.

Section A shows the earth foundation, which was flat.

Section B represents the stone foundation. This course was composed of flat stones laid by hand in two or more layers. The total width of this foundation was 18 feet, and the depth was from 9 to 10 inches.

Section C shows the layer of small stones, which were broken in place with hand hammers.

Section D shows the finished surface. This course was composed of stones broken by hand into sizes smaller than the underlying material. It was left to be consolidated by traffic. The total thickness of the road in the center was from 18 to 20 inches and at the sides from 12 to 14 inches.

TRÉSAGUET METHOD.

Fig. 3 illustrates the type of road constructed in France by Trésaguet from 1775 to 1830. After this period the Macadam method was used almost exclusively.

Section A shows the earth foundation parallel to the finished surface.

Section B represents the stone foundation, which was composed of flat stones laid on edge, lengthwise across the road, and beaten to an even surface. The depth of this foundation was about 5 inches.

Section C shows the small stones laid and beaten by hand hammers. The finished layer was composed of broken stones about the size of walnuts and was spread with a shovel.

Section D represents the finished road as consolidated by travel. The crown was made 6 inches, the width 18 feet, and the total thickness about 10 inches.

E shows the curbs, which were composed of rough, flat stones, set on edge. The upper edge was made flush with the surface.

MACADAM METHOD.

The Macadam method of construction was introduced in England and Scotland by a Scotchman, John Loudon Macadam (1756-1836). The chief features of Macadam's construction were a raised, thoroughly drained, and crowned earth foundation, stone broken to uniform size not to exceed 1½ inches, and the addition of no binding material to the broken stone. Macadam also insisted that the road should have a slight crown and that broken stone, when spread on the road, should be kept raked smooth until thoroughly consolidated by the traffic. This form of construction continued practically unchanged until the introduction of the road roller in about 1870.

During the past 40 years the methods of construction and maintenance have been greatly modified, though the same name is still given to roads of this class.

At the present time, the Macadam road is built in courses, with the coarser stones at the bottom and the finer on top. Stone screenings or sand are used for binding, while practically in every case the stone is broken by machinery.

Fig. 4 illustrates a Macadam road of the type constructed during the first period of Macadam construction, which began about 1816.

Section A shows the earth foundation, which was always made higher than the surface of the adjacent ground so as to facilitate the escape of water from the foundation and the surface. Macadam did not believe that an excavated foundation was necessary.

Section B shows the layer of hand-broken stone, with a depth of 10 inches. This stone was broken to sizes weighing 6 ounces, and no stone was permitted to exceed 1½ inches in its greatest diameter. The surface of the road was raked regularly during the process of consolidation. No rollers were used, and the stone was compacted by traffic.

Section C shows the finished road, from 16 to 18 feet wide. The crown was just enough to shed water—that is, from 4 to 6 inches. Macadam contended that the stones would lock or bond by virtue of their angularity and so make a water-tight crust, and that it was neither necessary nor desirable "to bond a road with earth, clay, chalk, or other material that would imbibe water or be affected by frost." The surface of the road was kept even and smooth by the addition of fresh material where necessary. This material was placed on the road in thin layers in damp weather in order that the new material might more readily bond and incorporate with the old.

TELFORD METHOD.

This form of construction takes its name from the celebrated engineer Thomas Telford (1757-1834), who, among many other notable things, constructed 920 miles of roads in the Highlands of Scotland and also a large mileage in the mountainous sections of Wales, as well as in the north of England. To-day the chief characteristic of the Telford road is a foundation of fairly regular stones, about 3 by 5 by 7 inches in their smallest dimensions, placed by hand on the wider of the long narrow faces and with the greatest dimension perpendicular to the axis of the road. The blocks are then "keyed in" by filling the interstices with stone spalls, chips, or small gravel. Any projecting points are broken off. On this foundation is placed a wearing surface of broken stone from 4 to 7 inches deep. Originally the Telford road was constructed with a flat subgrade, and a slight crown was obtained by using larger stones in the center. In present construction, however, the subgrade is given the same crown as the finished road, and stones of uniform size are used throughout. Formerly, too, the wearing surface was placed and consolidated in the same manner as the wearing surface of the old Macadam road.

The Telford foundation is used very generally in the construction of important roads in Austria-Hungary, Germany, Russia, Switzerland, and the Scandinavian countries. Some of the roads of England and Scotland which were formerly Macadam are proving too weak for the present heavy traffic and are being relaid with Telford foundations.

Fig. 6 illustrates a Telford road as constructed during the first period, which began about 1820.

Section A shows the earth foundation, from 16 to 20 feet wide, and flat.

Section B represents the Telford base, composed of stones about 7 inches in depth. No stone more than 3 inches wide was placed at the top.

Section C shows the top course, about 7 inches thick at the crown. It was composed of hand-broken stone, not heavier than 6 ounces, and passing through a circular ring not larger than 1½ inches in diameter.

Section D shows the finished road, bonded with 1 inch of gravel. The crown was made 6 inches for the road, which was surfaced to a width of 18 feet.

FOUNDATIONS OR SUBGRADES AND SHOULDERS.

In the construction of all types of gravel or Macadam roads it is necessary, in order to obtain the best results and to use surfacing material economically, to prepare the foundation or subgrade and shoulders of the road carefully. The subgrade should be brought approximately to the grade established for the road, and as much lower as the depth of the surfacing material to be used. It should then be compacted with a roller until it is hard and firm. If soft places develop during the rolling, they should be filled with good material and rolled again. This prevents the surfacing material from being pressed into the foundation, and consequently less material is required. The subgrade should also be finished with a crown for the reason just stated. If the surface is to be of uniform thickness, the crown of the subgrade is the same as for the finished road. If the surfacing material is to be thicker at the center than at the sides, the subgrade must be made to correspond. The shoulders are built up before the surfacing material is placed in position and serve not only to increase the width of the road but as a side support to hold the surfacing material while it is being rolled. They also keep it from wasting away into the side ditches. After the hardened surface is completed, the shoulders should be finished to correspond; shoulders are usually finished with a sharper crown than is given the hardened surface.

Fig. 5 shows several methods of improving and strengthening poor natural foundations. This is accomplished principally by drainage, and as the need for some such treatment occurs more generally in hilly or rolling country than elsewhere, this model represents a roadbed located partly in a cut and partly on a sidehill.

Section A represents a sidehill location, and shows a surface ditch at the top of the slope, a side drain opening into a culvert with a drop inlet, a Telford base, and a section of guard rail.

Section B shows a V stone drain foundation with a side outlet.

Section C shows a center drain with laterals and cobble gutters.

SECTION A—SURFACE DITCH, SIDE DRAIN, AND TELFORD FOUNDATION.

The surface water falling on a large area sloping toward the road is often kept from the road and out of the road gutters, where it usually does considerable damage, by a surface ditch such as the one represented in Fig. 5. The side drain is constructed to carry off the ground water which is often found in hilly sections. In the model the trench is represented to be 2½ feet deep, 12 inches wide at the bottom, and 18 inches wide at the top. On the bottom of the trench is placed about 2 inches of clean stone, and on this stone a tile pipe, usually about 5 inches in diameter, is laid. The pipe is laid without cement, and the loose stone is carefully filled around the sides and top of the pipe to the top of the trench. The side drain empties in some suitable outlet. For example, the one in this model empties in a drop inlet, which also serves as an outlet to the surface ditch. The drop inlet empties into a culvert, and the water is carried under the road. This type of inlet furnishes an easy means for inspecting and cleaning the culvert. It also prevents the bank from sliding and closing up the inlet of the culvert, which sometimes happens in hilly sections.

The Telford base is an old form of construction used largely in wet sections. This construction has been described under the heading "Telford method."

The guard rail shown in the model is to protect travelers along the steep slopes. The fence is usually painted to prolong its life and colored white to enable the public to discern the embankment at night. The posts are about 6 inches in diameter and about 7 feet long, and are set in the ground to a depth of 3½ feet. About 18 inches from the ground a plank, 2 by 6 inches, is notched into the posts. The top rail is then placed about 18 inches above the top edge of this plank. It may be either a plank, 4 by 4 inches, notched into the top of the post, or a plank, 2 by 6 inches, spiked to the top of the post, which has been sawed off with a slope of 3 inches.

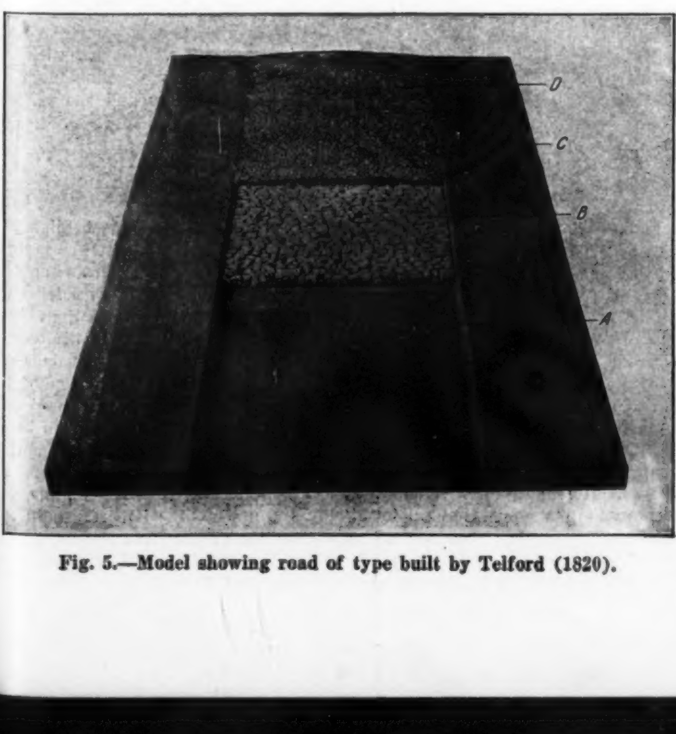


Fig. 5.—Model showing road of type built by Telford (1820).

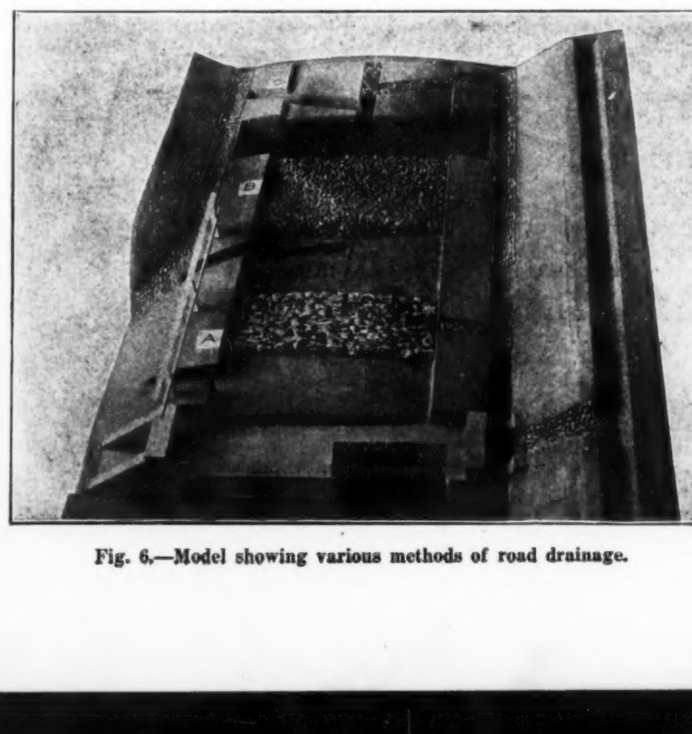


Fig. 6.—Model showing various methods of road drainage.

SECTION B—V STONE DRAIN FOUNDATION.

The V stone drain foundation is shown in section B of Fig. 5. This form of drainage is cheaper than the telford method and, in a section of country where rock abounds in ledges, it is also cheaper than the side drain construction. It is used entirely in wet and spongy sections. The water is held at the point of the V until a suitable outlet can be secured. The center is usually excavated 2 feet and the sides about 16 inches below the finished grade. The material excavated is thrown to the sides, forming the shoulders. In swamp sections it is sometimes necessary to haul material for the shoulders. The V drain is then filled with stone to a depth of 18 inches at the center and 10 inches at the sides. These stones grade from 8 inches in thickness down to a few inches. The large-sized stones are placed at the bottom, while the small stones are used at the top. The surface should then be rolled and the surfacing material spread and rolled. V drains are sometimes built of brickbats, slag, or even sand, or any material that will permit the water to seep rapidly to the point of the V. This type of construction permits the use of field stone of an inferior type and assists in clearing many farm lands of an otherwise waste product.

SECTION C—CENTER DRAIN WITH LATERALS AND COBBLE-PAVED GUTTERS.

The center drain with laterals, sometimes called a blind or French drain, furnishes another mode of draining the foundation of a road. As with the V drain, the water is brought to the center of the road and conducted to some suitable outlet. The model herewith shows these drains about 2 feet deep, about 12 inches wide at the bottom, and about 18 inches wide at the top. The trench is filled with stones from a few inches in thickness up to 8 inches.

The cobble gutters show an effective way of carrying away surface water on steep grades. The stones vary in thickness from 8 to 12 inches and are laid on a sand or gravel base. They are well rammed and given a coat of sand, which is carefully swept in, and then the stones are rammed again. These gutters are easily cleaned and protect the banks from being undermined, while at the same time carrying the water along rapidly without damage to the road.

(To be continued.)

Industrial Research in America*

Some Examples of the Harvests Gathered In

By A. D. Little

THE country of Franklin, Morse and Rumford; of McCormick, Howe and Whitney; of Edison, Thomson, Westinghouse and Bell, and of Wilbur and Orville Wright, is obviously a country not wholly hostile to industrial research or unable to apply it to good purpose, it is, however, not surprising that with vast areas of virgin soil of which a share might be had for the asking; with interminable stretches of stately forest; with coal and oil and gas, the ores of metals and countless other gifts of nature scattered broadcast by her lavish hand, our people entered upon this rich inheritance with the spirit of the spendthrift, and gave little heed to refinements in methods of production and less to minimizing waste. That day and generation is gone. To-day, its children, partly through better recognition of potential values, but mainly by the pressure of a greatly increased population and the stress of competition between themselves and in the market of the world, are rapidly acquiring the knowledge that efficiency of production is a sounder basis for prosperity than mere volume of product, however great. Many of them have already learned that the most profitable output of their plant is that resulting from the catalysis of raw materials by brains. A far larger number are still ignorant of these fundamental truths, and so it happens that most of our industrial effort still proceeds under the guidance of empiricism with a happy disregard of basic principles. A native ingenuity often brings it to a surprising success and seems to support the aphorism "Where ignorance is profitable 'tis folly to be wise." Whatever may be said, therefore, of industrial research in America at this time is said of a babe still in the cradle but which has nevertheless, like the infant Hercules, already destroyed its serpents and given promise of its performance at man's estate.

The long continued and highly organized research which resulted in the development of American agricultural machinery has led to the general introduction of machines which reduce the labor cost of seven crops $681,000,000 as measured by the methods of only fifty years ago.

The superhuman dexterity and precision of American Shoe machinery which have revolutionized a basic industry and reduced competition to the status of an academic question, present American industrial research at its best. They are not the result of the individual inspiration of a few inventors as is commonly supposed. They represent years of coordinated effort by many minds directed and sustained by constant and refined experimental research.

You need not to be reminded that the ubiquitous telephone is wholly a product of American research. Munchausen's story of the frozen conversation which afterward thawed out is a clumsy fable. Think of the Niagaras of speech pouring silently through the New York Telephone exchanges where they are sorted out, given a new direction and delivered audibly perhaps a thousand miles away. New York has 450,000 instruments—twice the number of those in London. Los Angeles has a telephone to every four inhabitants. Our whole social structure has been reorganized, we have been brought together in a single parlor for conversation and to conduct affairs because the American Telephone and Telegraph Company spends annually for research, the results of which are all about us, a sum greater than the total income of many universities.

The development of the automobile, and especially of the low-priced American car, is a thing of yesterday. To-day a single manufacturer turns out two cars a minute, while another is expanding his output to 500 cars a day. Every 23 days the total engine horse-power of new cars of one small type equals the energy of the entire Mississippi river development at Keokuk. Every 46 days this engine output rises to the total energy development at Niagara Falls. The amount of gasoline consumed upon our roads is equal to the water supply of a town of 40,000 inhabitants, and its cost on Sundays and holidays is $1,000,000.

It goes without saying that any such development as that of the automobile industry in America has been based upon and vitalized by an immeasurable amount of research, the range and influence of which extends through many other industries. It has accelerated the application of heat treatment more than any other agency. One tire manufacturer spends $100,000 a year upon his laboratory.

To no chapter in the history of industrial research can Americans turn with greater pride than to the one which contains the epic of the electrochemical development at Niagara Falls. It starts with the wonderful story of aluminum. Discovered in Germany in 1828 by Wohler, it cost in 1855 $90 a pound. In 1886 it had fallen to $12. The American Gastner process brought the price in 1889 to $4. Even at this figure it was obviously still a metal of luxury with few industrial applications. Hall in America and Heroult simultaneously in Europe discovered that cryolite, a double fluoride of sodium and aluminum, fused readily at a moderate temperature, and when so fused dissolved alumina as boiling water dissolves sugar or salt, and to the extent of more than 25 per cent. By electrolyzing the fused solution aluminum is obtained.

On August 26th 1895 the Niagara works of the Pittsburgh Reduction Company started at Niagara Falls the manufacture of aluminum under the Hall patents. In 1911 the market price of the metal was 22 cents and the total annual production 40,000,000 pounds.

A chance remark of Dr. George F. Kunz in 1880 on the industrial value of abrasives turned the thoughts of Acheson to the problem of their artificial production and led to the discovery in 1891 of carborundum and its subsequent manufacture on a small scale at Monongahela City, Pa. In 1894 Acheson laid before his directors a scheme for moving to Niagara Falls, when to quote his own words:—

"To build a plant for one thousand horse-power, in view of the fact that we were selling only one half of the output from a one hundred and thirty-four horse-power plant, was a trifle too much for my conservative directors, and they one and all resigned. Fortunately, I was in control of the destiny of the Carborundum Company. I organized a new board, proceeded with my plans, and in the year 1904, the thirteenth from the date of the discovery, had a plant equipped with a five-thousand electrical horse-power and produced over 7,000,000 pounds of those specks I had picked off the end of the electric light carbon in the spring of 1891."

The commercial development of carborundum had not proceeded far before Acheson brought out his process for the electric furnace production of artificial graphite and another great Niagara industry was founded. In quick succession came the Willson process for calcium carbide and the industrial applications of acetylene; phosphorus, ferro-alloys made in the electric furnace, metallic sodium, chlorine and caustic soda first by the Castner process, later by the extraordinary efficient Townsend cell, electrolytic chlorates and alundum.

In the year 1800 a young assistant of Lavoisier, E. E. du Pont by name, emigrated to this country with others of his family and settled on the banks of the Brandywine, near Wilmington, Delaware. He engaged in the manufacture of gunpowder. To-day the Du Pont Company employs about 250 trained chemists. The equipment of the "Eastern Laboratory," which confines itself to research concerned with high explosives, is housed in 76 buildings, the majority being of considerable size, spread over 50 acres. Since no industrial research laboratory can be called successful which does not in due time pay its way, it is pleasant to record that the Eastern Laboratory is estimated to yield a profit to its company of $1,000,000 a year. In addition to the generous salaries paid for the high class service demanded by the company, conspicuous success in research is rewarded by bonus payments of stock.

The Gayley invention of the dry air blast in the manufacture of iron involves a saving to the American people of from $15,000,000 to $29,000,000 annually. A modern furnace consumes about 40,000 cubic feet of air per minute. Each grain of moisture per cubic foot represents one gallon of water per hour for each 1,000 cubic feet entering per minute. In the Pittsburgh district the moisture varies from 1.83 grains in February to 5.94 grains in June, and the water per hour entering a furnace varies accordingly from 73 to 237 gallons. In a month a furnace using natural air received 164,500 gallons of water whereas with the dry blast it received only 25,524 gallons. A conservative statement according to Prof. Chandler is that the invention results in a 10 per cent increase in output and a 10 per cent saving in fuel.

Especially notable and picturesque among the triumphs of American industrial research is that by means of which Frasch gave to this country potential control of the sulphur industry of the world. There is in Calcasieu Parish, Louisiana a great deposit of sulphur 1,000 feet below the surface under a layer of quicksand 500 feet in thickness. Frasch conceived the idea of melting the sulphur in place by superheated water forced down a boring, and pumping the sulphur up through an inner tube. In his first trial he made use of 20 150 H.P. boilers grouped around the well, and the titanic experiment was successful. The pumps are now discarded and the sulphur brought to the surface by compressed air. A single well produces about 450 tons a day and their combined capacity exceeds the sulphur consumption of the world.

An equally notable solution of a technical problem which had long baffled other investigators is the Frasch process for refining the crude, sulphur-bearing, Canadian and Ohio oils. The essence of the invention consists in distilling the different products of the fractional distillation of the crude oil with metallic oxides, especially oxide of copper, by which the sulphur is completely removed while the oils distill over as oderless and sweet as from the best Pennsylvania oil. The copper sulphide is roasted to regenerate the copper. The invention had immense pecuniary value. It sent the production of the Ohio fields to 90,000 barrels a day and the price of crude Ohio oil from 14 cents a barrel to $1.00.

(To be continued.)

*Extract from the presidential address before the American Chemical Society.

Variability of Nebulae

THE question of the variability of the brilliancy is now discussed after having been considered as certain. Astronomers are to-day apt to look upon it as doubtful, and that on account of the difficulty of conceiving the mechanism of such a variation, as much in the case of resolvable nebulæ or masses of stars as in the case of non-resolvable or purely gaseous nebulæ. A nebula discovered by Hind in 1845, in the constellation of the Eagle, was considered as variable; quite recently, M. Borelly announced that at present it appears to be attaining a maximum state of brilliancy. M. Bigourdan shows that former observations do not confirm the variability. He insists on the interest of the fact noticed by M. Borelly, and on the importance just at present of the observation of the Hind Nebula, as this is just now very distinctly visible in instruments of average opening.—*Chemical News.*

Two Unsolved Problems of Astronomy*

Planetary Pertubations and the Moon's Motion

By Arthur B. Turner

The recent appearance of a valuable memoir[1] by Prof Eric Doolittle brings again forcibly to mind the fact that the Newtonian theory of gravitation is not in complete harmony with all astronomical observations. From the vague ideas of Ptolemy of a universal pervading force, through the observations of the skilful Tycho Brahe, through the empirical laws laboriously evolved by Kepler from these, we come to the transcendent genius of Newton, who showed that a force of attraction varying with the product of the masses of two bodies and inversely as the square of the distance between their centers was sufficient to explain the motion of the planets, their satellites and even the motion of comets. Since Newton, many other minds—like those of Lagrange and Laplace—have woven a wonderful fabric based upon this law of universal attraction. Several times when theory and observation did not agree, these mathematicians were tempted to abandon the law, but in each case a little more labor, a few more neglected terms of a series, and theory was found to agree with observation. Since the time of the Herschels, double star astronomy and still more recently the spectroscopic binaries have testified in favor of the same law in distant stellar systems, as far as the accuracy of our observations is able to show. But there are two cases where the refinements of mathematical analysis and the increased accuracy of observations have not succeeded in verifying the Newtonian law. Let us suppose that the solar system consists of the sun and Mercury. The planet Mercury would then describe an ellipse about the sun as a focus, due to their mutual attraction—an ellipse which would remain for all time fixed in size and position. As soon as we introduce another planet, as Venus, this equilibrium—if we may call it by such a term—is disturbed, and Mercury will now travel in an ellipse which varies continuously, but slowly, both in size and position. Each planet path of any planet is, as a consequence, a very complicated curve about the sun, no point of which, however, is very distant from the fixed ellipse of the undisturbed planet.

If upon the quiet surface of water in a vessel, water is allowed slowly to drop, the surface will be disturbed, the particles rising and falling as the ripples spread over it. At the same time the surface will be slowly raised, due to the increase of volume of the water in the vessel. The result is that every particle of the surface has two distinct motions (*a*) periodic (motion in ripple) and (*b*) progressive (rising of the level). When the powerful mathematical analysis is applied to planetary perturbations a similar two-fold nature is found to exist. That is, we have periodic perturbations and secular variations. The periodic perturbations depend on the relative positions of the two planets in their respective orbits, that is, upon their heliocentric longitudes. They are completed in most cases in a few revolutions of the two planets. The secular variations, on the other hand, depend upon the position of the two orbits to one another, and are entirely independent of the positions of the planets in their respective orbits. A famous example of the first class is the "long period" of Jupiter and Saturn, taking about 918 years to run its course—the time of a complete revolution of a point of conjunction. This perturbation displaces Jupiter a total of 21′ and Saturn 49′ in longitude. It was Laplace who brought, after much difficulty, this observed displacement into harmony with the Newtonian law. Examples of the second class are: (1) the line of apsides of Neptune's orbit makes a complete revolution in 540,000 years; and (2) the line of nodes of Mercury, a revolution in 166,000 years.

Some interesting facts can be stated regarding the second class of perturbations.

(*a*) Each planet's mean distance and consequently its year remains entirely free from any secular variation.

(*b*) The line of nodes and apsides revolve continuously.

(*c*) The inclination and eccentricity confine their variations within very narrow limits as shown by Laplace. [(*a*) and (*c*) insure the stability of the solar system.]

(*d*) The eccentricities and inclinations being small, also the masses of the planets being small, in comparison with the sun; the secular variation produced in any element by the remaining planets can be computed separately, and added algebraically to get the total secular variation of that element. Modern investigations, which include higher powers in the development of the perturbing function than those of Laplace, indicate that these facts in regard to the stability of the solar system are not strictly true.

In 1818 the astronomer Gauss proved that if the mass of each planet were spread over its orbit to form an elliptic ring of infinitesimal thickness, and with a density at each point inversely proportional to the velocity of the body at that point, the mutual attractions of such rings would change their shapes and positions, and these changes would be exactly the same as the secular variations of the elements. The American astronomer G. W. Hill has given a very accurate method,[2] based on this theorem of Gauss, for the practical calculation of these secular variations. Since 1896 there have been appearing from time to time in the *Astronomical Journal* applications of Hill's Method by Professor Eric Doolittle, of the University of Pennsylvania. Final results for the four inner planets have recently been published.[3] Professor Doolittle finds that observation[4] gives an excess of 45″.4 per century over the calculated motion of Mercury's perihelion; 10″.6 in case of the node of Venus; and 8″.7 in the case of the perihelion of Mars. The smallest of these residuals is over three times its probable error. The remaining variations agree with observation. The explanation of the above residuals is one of the old unsolved problems of astronomy. The first is the most important and was first stated by Leverrier in 1845 as 35″; Newcomb found it to be 43″. Since Leverrier's announcement astronomers have been looking for other masses—intra Mercurial planets—whose added attraction might harmonize the Newtonian law with observation. They used first the telescope, then later the camera during the total eclipses of the sun, but no images other than of known objects have ever been definitely seen. Director Campbell,[5] of the Lick Observatory, feels sure from the results of the Croker Eclipse Expedition to the South Seas in 1908, that there exists no planet as bright as the 8th magnitude nearer the sun than Mercury. Dr. Perrine was able on this expedition to photograph stars to the 9th magnitude. He estimated that it would take about a million planets of the 8th magnitude, 30 miles in diameter, to produce the observed motion of Mercury's perihelion. In 1895 Newcomb tried the hypothesis of placing a ring of finely divided material between the sun and Mercury, and a second hypothesis of a ring between Mercury and Venus having a mass of $\frac{1}{37500000}$ of the sun. Both rings were inclined to the ecliptic. Each of these suggestions he found gave rise to certain conditions which made them untenable. The zodiacal light which extends for more than 90 degrees along the ecliptic, on the two sides of the sun, is supposed by astronomers to be sunlight reflected from finely divided material in the neighborhood of the sun. In 1906 H. H. Seeliger supposed this material to be arranged around the sun in the form of ellipsoids of revolution. He then computed the secular variation produced by the attraction of the ellipsoids: equated these to the residuals as determined by Newcomb in his "Astronomical Constants," excepting the four eccentricities which he considered as not perturbed by the ellipsoids. The solution of these equations gave:

Density of inner ellipsoid $= 2.52 + 10^{-11}$ times sun's density.
Density of the outer ellipsoid $= 0.0026 + 10^{-11}$ times sun's density.
Total mass $= 35000 + 10^{-11}$ times sun's density.
Inclination of equator of inner ellipse = 6°.95
Longitude of node of inner ellipse = 40°.03.

The length of the axes of the ellipsoids and the position of the equator of the outer one were arbitrarily fixed. The total mass stated above has been computed as being comparable to $\frac{1}{27}$ of a cubic foot of water per cubic kilometer of space. It remains to be seen whether further observations upon the zodiacal light will strengthen this plausible hypothesis of Seeliger.

A. Hall[7] has tried the effect of changing the Newtonian law without adding any new masses to the solar system. His discussion is based on a theorem stated by Bertrand in 1873. That is, if the central force varies with the nth power of the radius vector, the angle θ between the maximum and the minimum radii vectors will be $\theta = \frac{\pi}{\sqrt{n+3}}$. When $n = -2$, which is the Newtonian law, $\theta = \pi$ and the perihelion is fixed. He also found that a value of $n = -2.00000016$ is sufficient to move Mercury's perihelion 43″ per century as found by Newcomb. There are no secular variations of the other elements due to this change in the value of n. But such a change Newcomb calculated would also make the moon's perigee move 1″.5 faster per year. E. W. Brown, of Yale, however, finds that the motion of the moon's perigee is in agreement with the Newtonian law.

The other old unsolved problem of gravitational astronomy was first stated by Halley, the friend of Newton, who found that the mean motion of the moon around the earth was slowly increasing; that is, the month was getting shorter. He arrived at this conclusion from a comparison of ancient with modern solar eclipses. It was left for Laplace, however, to apparently explain this phenomenon. It can easily be shown[8] that the average disturbing effect of the sun upon the moon—the earth, moon and sun being in a line—varies, approximately, inversely as $(1 - e^2)^{\frac{3}{2}}$ where e is the eccentricity of the earth's orbit. Therefore if the earth's orbit becomes more circular (i. e. its eccentricity diminished), the average disturbing effect of the sun upon the moon during a revolution of the earth will be weakened, and as a consequence the earth's attraction will tend to accelerate the moon's mean motions and bring it closer to the earth. The computed secular variation of the earth's orbit shows that its eccentricity is slowly decreasing, sufficient to cause a shortening of the mean distance of the moon from the earth 14 feet in 200 years, and if continued indefinitely would bring the moon down upon the earth. This decrease will continue, however, for about 24,000 years, the orbit of the earth becoming almost a true circle, after which interval the eccentricity will increase for several thousands of years. Laplace computed the acceleration of the moon's mean motion and found it to be 10″ per century. This was increased to 12″.5 by later astronomers, and agreed with the observed discrepancy obtained from the comparison of eclipses. In 1853 Adams reduced this to about half, finding that the former computations were rather rough approximations. The present value as found by Brown, and considered as accurate, is 5″.91. In 1877 Newcomb, from the comparison of the records of lunar eclipses, kept by Ptolemy and the Arabians, found the moon's observed acceleration to be 8″.3 per century. This still leaves a difference of 2″.4 per century between theory and observation. There are also some unexplained periodic perturbations of the moon, thought to be due to the action of planets, which complicates the solution of the problem of the moon's motion.

As a result, the tables which predict the longitudes of the moon for given dates, do not agree with observation. For instance, in 1910.5 the moon's longitude was 4″.5 in excess of its predicted position.[9] Also the computed times of contact in the case of solar eclipses are found to be in error a few seconds, and the plotted path of totality on the earth slightly shifted.

The early suggestion in 1856 by Ferrel that the discrepancy might be due to the lengthening of the unit of time, the day, by tidal friction or other causes seems to meet with the approval of most of the present day astronomers. Some, however, are suggesting a possible explanation through the finite propagation of gravitation based on the Principle of Relativity.[10] Still others suppose that during a lunar eclipse the earth acts as a partial absorber of the gravitational force between the sun and the moon.[11]

In conclusion it is well to remember that the discovery of aberration, nutation and the planet Neptune were due to the presence of small residuals; and that the whole structure of modern investigations depends upon the explanation of small quantitative changes. Some day this excess motion of Mercury and the moon may lead to the discovery of some phenomena as simple as those given above. The changing of the law seems further from our minds than the presence of some subtle force like light pressure or magnetism.

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* Reproduced from the *Journal of the Royal Astronomical Society of Canada*.

[1] "The Secular Variations of the Elements of the Orbits of the Four Inner Planets." *Transactions of the American Philosophical Society*, Volume XXII, Part 2.

[2] On Gauss's Method of Computing Secular Perturbations. *Astronomical Papers of the American Ephemeris*, Vol. I.

[3] *Transactions of the American Philosophical Society*. Vol. XXII, Part 2.

[4] Newcomb—"Astronomical Constants."

[5] *Popular Science Monthly*, Vol. LXXIV.

[6] Doolittle—"Secular Variations of the Elements of the Four Inner Planets."

[7] *Astronomical Journal*, Vol. XIV.

[8] Moulton's *Celestial Mechanics*, p. 242.

[9] *The Observatory*, No. 454, p. 391.

[10] Poincaré *Comptes Rendus*, Vol. CXL., p. 1504: C. O. James, *Astronomical Journal*, 633–634.

[11] W. De Sitter, *The Observatory*, No. 454.

The eighty horse-power Nieuport monoplane, military model.

Espanet starting in Anjou Prize Contest in his Nieuport military model

The Nieuport Monoplane

A Machine Whose Success Depends On Its Wing Section

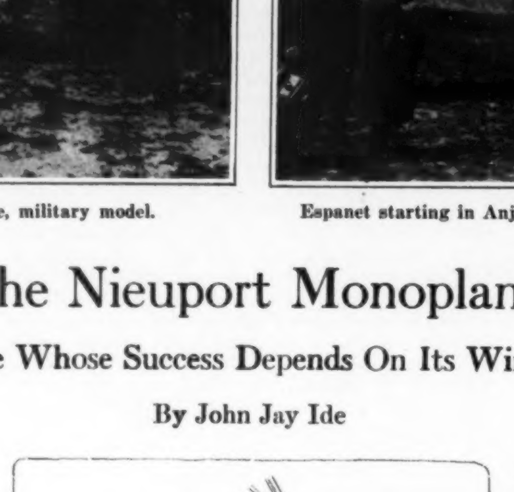
By John Jay Ide

By the death of Edouard Nieuport in the Autumn of 1911 the cause of aviation in France experienced the greatest loss it has yet sustained. If he had been spared we should probably not see, as we do now, aeroplane constructors still engaged in making detail refinements to his designs. Such a genius as he would undoubtedly have been able to prevent the present stagnation of design. This lack of real improvement has alienated what once bid fair to be a very promising market, viz: the well-to-do sportsman. At present almost all the aeroplanes sold in France are for military service, the French army being the heaviest purchaser in this class. It will be seen that the patronage of the army is almost essential to the existence of an aviation firm in France. In fact the government's failure to buy aeroplanes from Roger Sommer brought about his recent retirement from the industry. The same cause could be held responsible for the disappearance of several other firms. The initial impetus given by Nieuport to his firm was so great that it is still in a flourishing condition despite the fact that it has made little actual progress since his death.

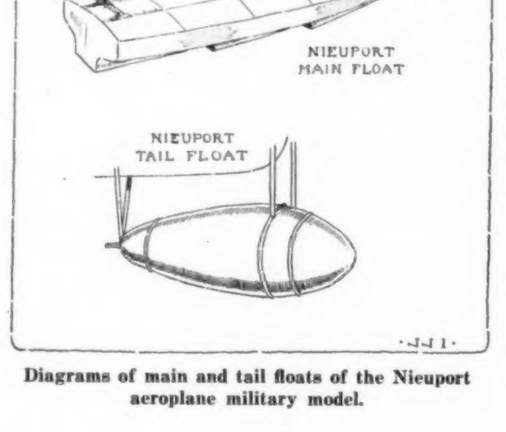
Before he became attracted to aviation Edouard Nieuport was for years known to the motoring community abroad as a manufacturer of ignition specialties. When he designed his early aeroplanes he went further than the Wrights in that not only were the engines his own manufacture but also the magnetos and plugs. In 1910 he had evolved a small monoplane with a 28 horse-power two-cylinder motor which had greater speed than that displayed by Grahame-White's 100 horse-power Blériot-Gnôme when he won the Gordon-Bennett cup at Belmont Park in October of that year.

The high speed of the Nieuport was due largely to the employment of an extremely efficient wing section and to the designer's study of the reduction of head resistance which resulted in a special form of fuselage. These two characteristics of the Nieuport have been continued with very little change down to the current military model which the accompanying scale drawings represent.

The wings are double surfaced and taper toward the tips. Their section somewhat resembles that advocated by Horatio Phillips. The lower surface near the entering edge has a convex curve where it passes under the forward spar. The trailing edge is given a slightly upward turn



Diagrams of main and tail floats of the Nieuport aeroplane military model.



Detail of the Nieuport aeroplane control in the military model.

instead of forming a more or less tangential continuation of the cambered portion of the plane as in the Blériot and most other wings. The maximum camber is about $3\frac{3}{4}$ inches. The angle of incidence is extremely small.

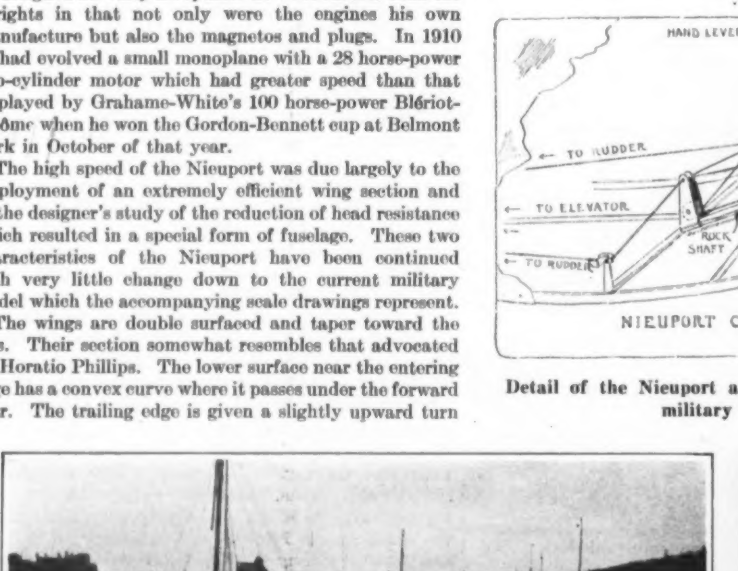
The wings are set at a very slight dihedral angle and an interesting feature of their construction is that the *I*-section main spars of ash are not of even section along their entire length but vary in thickness according to the strains imposed. Thus it has been found out that the greatest strength is necessary at a point situated a few feet from the inner end of the spar, the stay wires being taken into account in this calculation. The main spars are braced well forward to the skid, stranded wire cables of $\frac{1}{4}$ inch diameter being employed for the purpose. The upper stays are of wire $\frac{1}{8}$ inch in diameter.

The fuselage, entirely covered in with fabric, is of approximate stream line form as seen from the side but is rectangular in section. It is very deep in the region of the pilot's seat in order that his whole body may be enclosed. The maximum section of the body longitudinals is $1\frac{1}{8}+1\frac{1}{2}$ inches. The greatest width of fuselage is 3 feet and greatest depth 3 feet 6 inches.

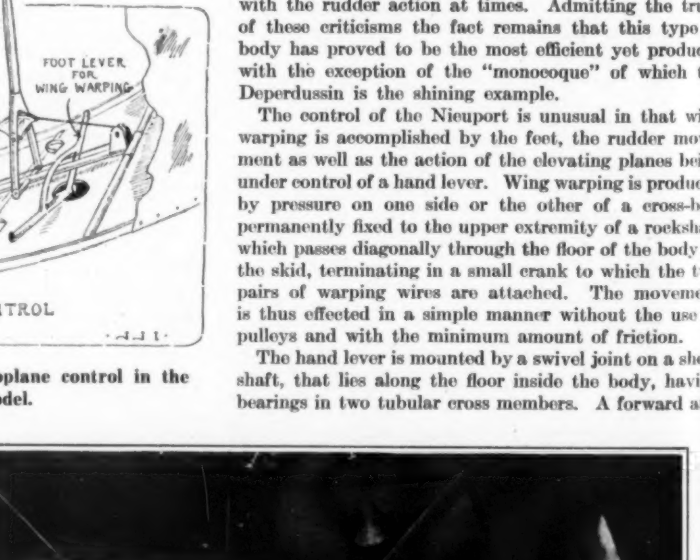
This type of body has been criticized as causing a great deal of resistance when turning owing to the great amount of surface normal to a side wind. Covering in the rear part with fabric also, it is claimed, interferes with the rudder action at times. Admitting the truth of these criticisms the fact remains that this type of body has proved to be the most efficient yet produced with the exception of the "monocoque" of which the Deperdussin is the shining example.

The control of the Nieuport is unusual in that wing warping is accomplished by the feet, the rudder movement as well as the action of the elevating planes being under control of a hand lever. Wing warping is produced by pressure on one side or the other of a cross-bar, permanently fixed to the upper extremity of a rockshaft which passes diagonally through the floor of the body to the skid, terminating in a small crank to which the two pairs of warping wires are attached. The movement is thus effected in a simple manner without the use of pulleys and with the minimum amount of friction.

The hand lever is mounted by a swivel joint on a short shaft, that lies along the floor inside the body, having bearings in two tubular cross members. A forward and



The Nieuport hydro-monoplane. Pilot, Ch. Weyman.



Landing chassis of the 80 horse-power military model.

backward movement of this lever operates the elevator through the agency of stranded wire cables of ⅛ inch diameter passing around pulleys at both ends of the short rockshaft. A lateral motion of the lever actuates the rudder wires by means of a crank which is really formed by the extension of the rear pulley sheave and rigidly attached to the rockshaft.

Seating accommodation in the military model is provided for two, the pilot placed forward and the passenger immediately behind him. On some machines of this type the rear seat is wide enough for two persons if necessary. The control is not in duplicate.

It may be supposed, owing to the great depth of the body and low position of the seats, that the pilot's view would be somewhat restricted, but in this regard it must be remembered that his seat is not far behind the leading edge of the wings, and that the machine flies with the tail unusually high. The tail members, all of which are perfectly flat, consist of steel tubular frames covered on both sides with fabric.

The landing chassis is composed of a long central skid connected to the body by oval section steel tubes. A spring leaf axle passing through the apex of the central inverted triangle has a wire wheel of 2 feet 10 inches diameter at each extremity. A spoon attached to the forward end of the skid prevents the point digging into the ground on landing after the fashion of the old Antoinettes. The undercarriage is composed entirely of steel.

In the particular machine illustrated the motor is an 80 horse-power Gnôme driving a Chauviere tractor of 8 feet 2 inches diameter and 6 feet 7 inches pitch. Gnôme motors of 50 and 100 horse-power are also regularly fitted to this model. The engine, of whatever power, is supported by bearings front and rear, not being overhung. To reduce its head resistance a dome is fitted over the front, a quarter segment of it being cut away to admit sufficient air for cooling. The surface is 241 square feet and the weight with the 80 horse-power motor is about 750 pounds (empty). The speed is from 68 to 76 miles per hour depending upon the motor.

. . . .

The Nieuport hydro-monoplane, which has recently come into such prominence, was designed with the military model as a basis. Indeed the two machines are practically identical except insofar as the newer model is affected by its nautical use.

The alighting gear consists of two floats below and slightly forward of the centre of gravity, and a small float supporting the tail. Formerly single step floats were employed but the main floats of the latest models are of the triple step type capable of fore-and-aft adjustment. They are set wide apart and strongly braced to the body by elliptical section steel members forming a triangular construction. At the bases of the forward struts are eyebolts to allow for towing.

Cypress is the wood used for the construction of the sides and bottom of the main floats, the top being covered in with varnished canvas. On either side of the rounded and tapered nose of each float a fin projects designed to prevent the float burying itself in a heavy sea and also to assist in keeping spray clear of the propeller.

The small torpedo shaped float under the tail is made of thin wood and capped with a metal hemisphere. This float serves merely to keep the rear off the water when at rest, lifting free as soon as the machine gets under way. The tail has a vertical pin below as well as above the fuselage in order to counteract the effect of the side surface of the floats.

A change has been made in the building of the fuselage strenghtening it to withstand the heavier strains that alighting on the water calls upon it to bear. The vertical struts in the body are of steel tubing although the longitudinals and other portions of the body are still made of wood. The pilot is protected by a mica screen attached to the mast and behind him is a wide seat for two passengers. In the rear of the seats is a locker.

A good point is the fitting of a starting handle within easy reach of the pilot so that the engine can be set in motion without the aid of mechanics or requiring either of the passengers to get out of the machine. This is, however, of use only when the engine is warm as otherwise priming is generally necessary.

A Gnôme engine of 100 or 160 horse-power is fitted as standard, driving an 8-foot 5-inch Chauvière tractor the blades of which are tipped with metal as a protection against spray. The weight empty is 1,430 pounds and ready for flight 2,400 pounds. The surface is 241 square feet. With the 100 horse-power motor the speed is 72 miles per hour. The price in Paris is $6,000.

The main floats are 10 feet 5 inches long, 3 feet 7 inches wide, and 1 foot 8 inches deep. Their capacity is 407 gallons and they weigh 220 pounds. The capacity of the tail float is 33 gallons and its weight 22 pounds.

. . . .

The single seated racing model was first exhibited at the last Paris Salon. It is a smaller edition of the standard machine with changes in the chassis. To attain high speed the designer has not resorted to high engine power. He has kept to the 50 horse-power Gnôme and to increase the speed has aimed at still further improving the efficiency of the machine by cutting down head resistance.

This is chiefly noticeable in the all steel landing gear which comprises a transverse spring with only two laminations forming the axle on the extremities of which two pneumatic tired wheels are mounted. This is attached to the fuselage by an inverted pyramidal structure the rear members of which are carried forward to form the skid.

As a light construction having little head resistance, this landing gear is perhaps good, but in practice it would prove extremely treacherous. As long as it were used only on smooth ground it might stand up to its work all right—that is, if it were in the hands of a skilful pilot. What would happen over rough ground one dreads to imagine. There is a light cane skid under the empennage.

There being no horizontal skid it is impossible to arrange the warping as before. On this machine it is operated by bell cranks, just below the fuselage, worked by the feet as usual. The mast is modified to allow of rapid dismounting of the wings which are folded against the body for road transportation. The wings have noticeably less curvature and incidence than on the other models. They are stayed on the underside by four cables—two to each spar.

Like the new military model a cowl is fitted over the front of the motor. The tractor is a Régy. The span is 29 feet, length 22 feet 10 inches, and surface 139 square feet. The weight (empty) is 513 pounds and speed 80 miles per hour. The price for delivery in Paris is $5,000.

. . . .

The fourth model is the classic single seater driven by a 28 horse-power Nieuport two-cylinder motor. In all essentials this machine has remained unchanged for three years, a striking commentary on the genius of its designer. As a good reliable all around touring vehicle it vies with the 50 horse-power Morane-Saulnier.

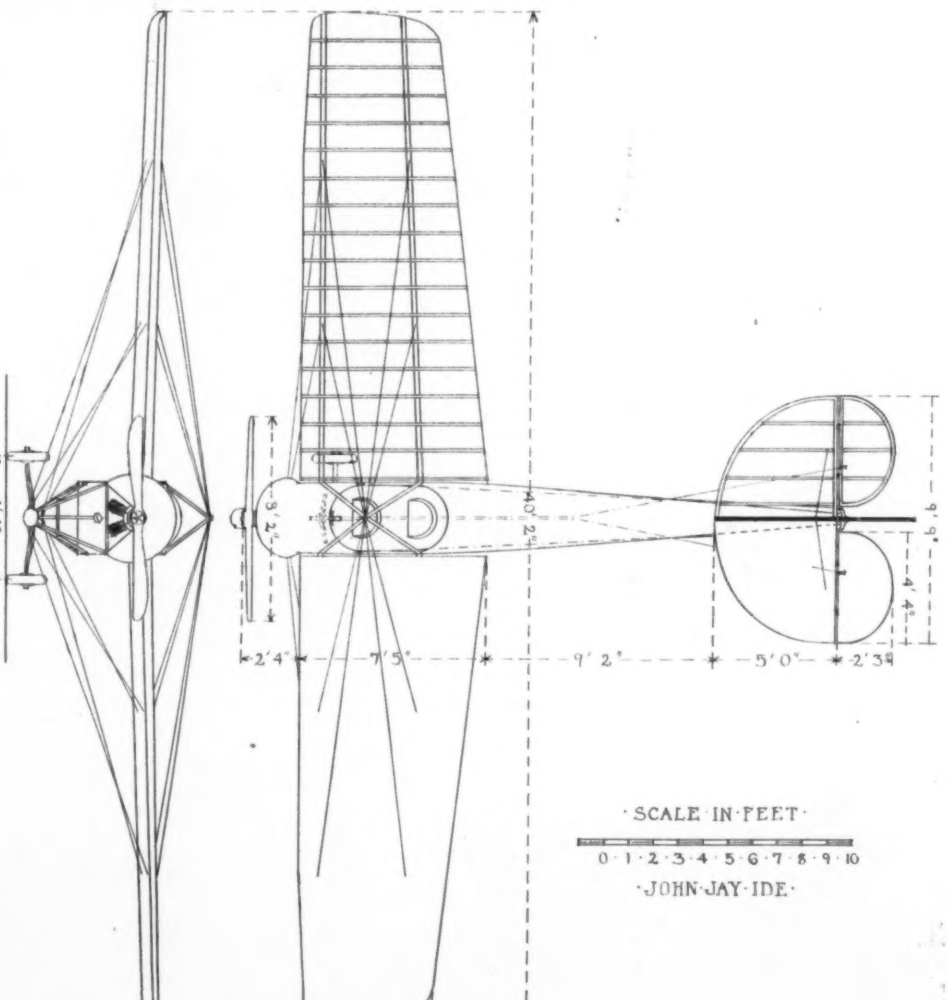
The span is 28 feet, length 23 feet, and surface 155 square feet. The weight (empty) is 570 pounds. With a Régy tractor it travels 66 miles per hour. It can be bought in Paris for $3,600.

. . . .

In 1911 the Nieuport piloted by Weymann won the Gordon-Bennett cup and the French Military Trials. Helen made a world's record for a flight in a closed circuit in the autumn of that year. Two Nieuports driven by Helen and Espanet started in the Grand Prix of the Aero Club de France held over the Anjou Circuit June 16th and 17th, 1912. Helen was almost immediately eliminated by the breakage of a valve in his 70 horse-power Gnôme. Espanet, carrying a passenger, was the first to complete the initial lap but on the second round a piston of his 80 horse-power Gnôme seized and brought him down. Espanet won the Prix d' Anjou, held over the same course on June 17th, by reason of the fact that he carried a passenger and therefore under the rules had his time reduced by one sixth. His actual time was slower than that of either Bobba or Brindejonc des Moulinais, who flew single seated Morane-Saulnier monoplanes.

On the third day of the St. Malo hydro-aeroplane competition, held in August 1912, Weymann in his 70 horse-power machine with two passengers flew from St. Malo to the Island of Jersey and back, a total of 120 miles, in 1 hour 41 minutes and 24 seconds, thus winning the race. On account of penalties incurred on the two previous days, he was placed fifth in the general classification, the winner being Labouret who drove an Astra biplane.

The hydro-aeroplane meet held at Monaco April 7th to 16th, 1913, was somewhat of a disappointment in so



Details of the Nieuport monoplane. Type IVM.

far as actual performances went. When one remembers, however, the extremely rough sea and high wind which prevailed during part of the meeting the wonder is that the machines behaved as well as they did. They were given as hard a test as the most exacting critic could wish.

Two Nieuports, driven by Weymann and Espanet, succeeded in completing the preliminary trials, thus qualifying for the Grand Prix, held April 12th, which consisted of a 55-mile flying cruise over sea from Monaco to Beaulieu, back along the coast to San Remo, and thence home to Monaco. The other competitors were Fischer on an H. Farman, Gaubert on an M. Farman, Bregi and Moineau on Bréguets, and Prevost on a Deperdussin. Nine machines failed to fulfill the preliminary requirements which were designed to thoroughly test the navigability of these combined sea and air craft.

Weymann in his 160 horse-power machine got away safely, but Espanet, with only 100 horse-power, attempting to rise quickly struck a wave with his left float and had to signal for a boat to stand by while he made for port. On reaching Beaulieu, Weymann attempting to fulfill the rule for 500 metres to be covered in Beaulieu Bay on the surface of the water, was the victim of a sensational accident. He was preparing to alight when the tail of his machine dropped into a hollow of the sea causing the monoplane to turn over on its back, he and his mechanic being prisoners in the fuselage. The machine described a complete somersault and the fuselage broke in two, letting the tail and rear float go free. Then it again turned over slowly on its back in which position it lay with its floats partly out of water until hauled ashore. Between the first and second stages of this "looping the loop" Weymann and his mechanic had managed to scramble out and were quickly picked up by one of the motor boats standing by. Owing to the extremely rough sea and high wind none of the competitors were able to complete the course, Moineau who reached San Remo, being awarded 13,000 francs.

In the International Sporting Club race held April 15th, Espanet succeeded in getting third place with 118 miles. The winner was Gaubert on the Maurice Farman, who, under almost insuperable difficulties in the shape of a series of minor accidents to his machine, covered 168 miles in 10 hours. Brégi on the Bréguet took second place with 142 miles.

The Jacques-Schneider cup race, which occurred April 16th, resolved itself into a duel between Weymann representing America and Prévost (Deperdussin). Weymann was ahead until the 150th mile when his engine seized owing to lack of oil, Prevost alone finishing the 175-mile course. Espanet abandoned the race after covering 44 miles.

Scientific Management*

The Present State of the Art

During the past few years a number of striking phenomena, in connection with industrial management, must have been evident even to the most superficial observer. The more important are:

a. The widespread, popular interest in the subject which had its rise in a statement made before the Interstate Commerce Commission in a hearing on the matter of proposed advances in freight rates by carriers, that it was estimated that by the application of newly discovered principles of management "in the railroad operation of this country an economy of $1,000,000 a day is possible," and further that these principles can be applied with equal success "in every form of business activity."

b. The suddenly intensified interest in the subject on the part of the employers and business executives in many lines of activity, shown by lectures, addresses, professional papers and reports presented to their associations.

c. The opposition of labor unions to the newer methods of management, shown by statements of labor leaders, in a few instances by strikes, and by an attempt to prohibit by law the use of some of these methods in Government shops.

d. Governmental recognition of the matter shown by the appointment of a special committee of the House of Representatives to investigate systems of management in Government arsenals and shops, which reported in March, 1912; by the appointment of a civilian board by the Secretary of the Navy to investigate management in the navy yards, which reported in July, 1911; and by Senate bill S 6172, now in committee, which is intended to prohibit time study and the payment of premiums or bonus on Government work.

e. The rapidity with which literature on the subject has accumulated.

f. The formation of two societies having as an aim the furtherance of the application of the principles of management.

g. The separation of persons interested in the matter into two camps, one of enthusiastic advocates, the other of vigorous opponents of what is called the new element in management.

h. The unquestionable proof of the advance that can be made in unskilled work, as shoveling materials, and in ancient trades, as bricklaying, by the application of the principles of management. This is the most striking phenomenon of all.

THE PRINCIPLES OF MANUFACTURE

A brief review of the beginnings of modern industry will enable the present to be more truly judged. Modern industry is variously stated to have begun in 1738 with Wyatt's invention of a spinning machine, or in the period 1750-1800 with the development of the steam engine and power loom. Early British economists, including Adam Smith and Charles Babbage, held that the principle of the *division of labor*, was the basis of manufacture.

It appears, however, that another principle is the basic one in the rise of industry. It is the *transference of skill*. The transference of skill from the inventor or designer to the power-driven mechanism brought about the industrial revolution from handicraft to manufacture. We will refer to this principle frequently in showing the meaning and position of management in industry.

No better single illustration of the application of this principle can be found than in the invention of the lathe slide rest by Henry Maudslay in 1794. This has been ranked as second only to the steam engine in its influence on machinery building, and thus on industrial development. The simple, easily controlled mechanical movements of the slide rest were substituted for the skilful human control of hand tools. So complete has been this transference of skill, that to-day, hand tooling is a vanished art in American machine shops. After the traditional skill of a trade, or the special, peculiar skill of a designer or inventor, has been transferred to a machine, an operator with little or no previously acquired skill, can learn to handle it and turn off the product.

Methods of analyzing and recording operations were early developed, as shown by the accompanying exhibits, Tables 1 and 2.

Thus we see the application of the principle of *transference of skill* at the basis of the development of the industry, and an early appreciation of the value of the detailed study of operations in making that transference more complete. But the machine was the viewpoint. It was looked upon as the producing unit. Combined and contrasted with this was a lack of knowledge of scientific principles and their sure application.

Babbage emphasizes the need of perfect drawings as an essential to the success of machine building, and he also points out that in order to succeed in a manufacture, not only good machinery is necessary, but the domestic economy of the factory must be carefully regulated.

These opinions foreshadow modern methods of thinking out the work in advance and transferring this thought to the workmen. The subsequent development has had the effect of advancing still further the division of labor, and beginning the division of thought. The drafting room presents the first example of the trend, in its collection of engineering data, in its prediction of results and the formation of staff organization.

But from the period of the last quotation almost to the present, there has been no change in the basic principles discovered and applied in industry. There has been nothing but an extension of those already known. The place of greatest advance has been the drawing room. The art of machine design has been greatly developed. The last half of the last century saw a tremendous increase in inventions, a tremendous furtherance of the

TABLE 1.—OPERATIONS IN PIN MANUFACTURE IN FRANCE IN 1760

	Name of the Process	Time of Making 12,000 Pins, Hour	Cost of Making 12,000 Pins, Pence	Workman usually Earns per Day, Pence	Expense of Tools and Materials, Pence
1	Wire	....	....	....	24.75
2	Straightening and Cutting	1.2	0.5	4.5	....
3	Coarse Pointing	1.2	0.625	10.0	....
	Turning Wheel *	1.2	0.875	7.0	....
	Fine Pointing	0.8	0.5	9.375	....
	Turning Wheel	1.2	0.5	4.75	....
	Cutting off Pointed Ends	0.6	0.375	7.5	....
4	Turning Spiral	0.5	0.125	3.0	....
	Cutting off Heads	0.8	0.375	5.625	....
	Fuel to Anneal Heads	....	....	....	0.125
5	Heading	12.0	0.333	4.25	....
6	Tartar for Cleaning	....	....	....	0.5
	Tartar for Whitening	....	....	....	0.5
7	Papering	4.8	0.5	2.0	....
	Paper	....	....	....	1.0
	Wear of Tools	....	....	....	2.0
		24.3	4.708		

* The expense of turning the wheel appears to have arisen from the person so occupied being unemployed during half his time, while the pointer went to another manufactory.

Babbage further comments on the use of the watch to time operations. We quote from his instructions to one making such observations and using a skeleton form that he recommends: "In filling up the answers which require numbers, some care should be taken: for instance, if the observer stands with his watch in his hand before a person heading a pin, the workman will almost certainly increase his speed, and the estimate will be too large. . . . The number of operations performed in a given time may be frequently ascertained when the workman is quite unconscious that any person is observing him. Thus the sound made by the motion of a loom may enable the observer to count the number of strokes per minute, even though he is outside the building in which it is contained."

TABLE 2.—OPERATIONS IN PIN MANUFACTURE IN ENGLAND ABOUT 1830

	Name of the Process	Workmen *	Time of Making 1 Pound of Pins, Hour	Cost of Making 1 Pound of Pins, Pence	Workman Earns Per Day s. d.	Price of Making Each Part of a Single Pin in Millionths of a Penny
1	Drawing Wire	Man	0.3636	1.2500	3 3	225
2	Straightening the Wire	Girl	0.3000	0.1420	0 6	26
		Woman	0.3000	0.2840	1 0	51
3	Pointing	Man	0.3000	1.7750	5 3	319
4	Twisting and Cutting the Heads	Boy	0.0400	0.0147	0 4½	3
		Man	0.0400	0.2103	5 4½	38
5	Heading	Woman	4.0000	5.0000	1 3	901
6	Tinning, or Whitening	Man	0.1071	0.6666	6 0	121
		Woman	0.1071	0.3333	3 0	60
7	Papering	Woman	2.1314	3.1973	1 6	576
			7.6892	12.8732		2320

* Number of Persons Employed: Men, 4; Women, 4; Children, 2. Total, 10.

* Abstract of majority report of the committee on administration of the American Society of Mechanical Engineers: James M. Dodge, Chairman, L. P. Alford, O. M. Bates, H. A. Evans, Wilfred Lewis, W. L. Lyall, W. B. Tardy, H. R. Towne.—Published in *Industrial Engineering*.

application of transference of skill to machines and tools. The skeleton of an industrial organization of this period, one that was too large for a single executive to manage, consisted of a designing department, and a production department, each with a head responsible to the manager.

The first of these, the one that was the means of embodying skill in the machinery and tools of production, was highly developed and organized. Experiment, research and detailed study were constantly resorted to, to aid in reaching the desired result. Not infrequently the manager or chief executive devoted much of his own time to this part of the business.

The production department presented a contrasting condition. The workmen were given the tools and machine designed in the drawing room, and, using their own unaided skill, were expected to produce work of the desired quality and quantity. Except in rare instances, no effort was made to transfer the skill of the management to the production department and the employees, or to undertake the division of executive thought. Very little consideration was given to the workmen as a producing unit.

FEATURES OF THE CHANGE.

Within the past 20 or 25 years certain changes have taken place in the attitude of many production managers toward the problems that they face and the forces and means that they control. An increasing amount of attention is being given to the worker. An early evidence was the development of profit-sharing, premium and bonus systems to reward increased effort and output. There followed welfare work, industrial betterment movements, the adoption of safeguards and regulations to minimize industrial accidents, the substitution of the principle of accident compensation for employers' liability and an improvement in the physical surroundings and conditions of factories.

Another tendency, less pronounced in character, has as its object the improvement of the personal relations between employee and employee and between employee and employer. It is an effort to establish the best of factory working conditions in those things not physical in nature, to develop and maintain a shop atmosphere free from all harassing and hindering influences. It is an attempt to make use of the results of experimental psychology, in improving working conditions.

But the most important change and one that comprehends the others, is in the mental attitude toward the problems of production. The tendency is toward an attitude of questioning, of research, of careful investigation of everything affecting problems in hand, of seeking for exact knowledge and then shaping action on the discovered facts. It has developed the use of time study and motion study as instruments for investigations, the planning department as an agency to put into practice the conclusions drawn from the results of research, and methods of wage payment which stimulate co-operation.

All of these changes have affected the production department much more than the designing department. The effect is to extend the principle of transference of skill to production, so that it completely embraces every activity in manufacture. The skill of the management is consciously transferred to all of the operations of the factory.

DEFINITION OF THE NEW ELEMENT IN THE ART OF MANAGEMENT.

Requests by the committee for a definition of the new element in the art of management brought forth a difference of opinion as to its existence. The opposed view is given in the following quotations:

"I am not aware that a new element in the art of management has been discovered——."

"There have been no new discoveries in scientific management of industrial institutions. Common-sense men have used common-sense methods always. The term 'scientific management' is a catch word which assumes that industrial institutions have not been scientifically managed—which is not the case. My experience and the experience of my friends has been that there has been no new element injected into the art of management."

"In the writer's opinion there is very little that is new about it (the art of management). There is hardly any part of it that has not been practised by managers for the past 100 years. The trouble is there are not enough managers with sufficient initiative to set system moving properly."

"—— the problem presented is not the adoption of something entirely new; but rather the extension to every detail of our work of something which we have already tried."

On the other side of the question, from a large number of definitions of this new element we select the following as very nearly conveying, taken together, the complete conception as our investigation has disclosed it:

"The best designation of the new element I believe to be 'scientific management.' This term already has been adopted quite generally, and although frequently misused, carries with it the fundamental idea that the management of labor is a process requiring thorough analytical treatment and involving scientific as opposed to 'rule of thumb' methods."

"The writer ventures to define the new element briefly, but broadly, as: The critical observation, accurate description, analysis and classification of all industrial and business phenomena of a recurring nature, including all forms of co-operative human effort and the systematic application of the resulting records to secure the most economical and efficient production and regulation of future phenomena."

"Stripped of technicalities the method of the modern efficiency engineer is simply this: First, to analyze and study each piece of work before it is performed; second, to decide how it can be done with a minimum of wasted motion and energy; third, to instruct the workman so that he may do the work in the manner selected as most efficient."

"The Taylor System is not a method of pay, a specific ruling of account books, not the use of high speed steel. It is simply an honest, intelligent effort to arrive at the absolute control in every department, to let tabulated and unimpeachable fact take the place of individual opinion; to develop 'team play' to its highest possibility."

"As we conceive it, scientific management consists in the conscious application of the laws inherent in the practice of successful managers and the laws of science in general. It has been called management engineering which seems more fully to cover its general scope than science."

These quotations convey the ideas of a conscious effort to ascertain and study facts and systematically to apply them in instructing the workmen and in controlling every department of industry. Setting these against the underlying principle of the transference of skill, we conceive the prominent element in present-day industrial management to be: *The mental attitude that consciously applies the transference of skill to all the activities of industry.*

LABOR-SAVING MANAGEMENT.

During the development of popular interest in the subject, the term "scientific management" has been generally and loosely applied to the new system and methods. This is commonly taken to mean that there is a science rather than an art of management. A truer interpretation is that it means management using methods, these being taken largely from the sciences of physics and psychology.

The expression "labor-saving management" better conveys the meaning of the movement. It has the further advantage of being easily and surely understood because of its strict analogy with the term "labor-saving machinery." It is no chance that puts these two terms, labor-saving machinery and labor-saving management, in conjunction, for the first is the past development and the second the present trend of industry, and they will be closely and inevitably associated in the successful manufacturing of the future. Throughout the following pages of this report the terms "industrial management" and "labor-saving management" are used, the first to denote the subject broadly, the second the newer attitude.

THE REGULATIVE PRINCIPLES OF INDUSTRIAL MANAGEMENT.

In our investigation, preparing for this report, one correspondent wrote as follows:

"The regulative principles of management along scientific lines include four important elements:

"*a* Planning of the processes and operations in detail by a special department organized for this purpose. *b* Functional organization by which each man superintending the workman is responsible for a single line of effort. This is distinctly opposed to the older type of military organization, where every man in the management is given a combination of executive, legislative and judicial functions. *c* Training the worker so as to require him to do each job in what has been found to be the best method of operation. *d* Equable payment of the workers based on quantity and quality of output of each individual. This involves scientific analysis of each operation to determine the proper time that should be required for its accomplishment and also higher payment for the worker who obtains the object sought."

Another correspondent finds the solution of problems of management in the observing and regulating of three classes of industrial phenomena:

"*a* The economic results of different arrangements and forms of materials and operations upon them, either to produce equipment or product. This covers the whole field of recorded experience from invention and design of product and tools down through the successive shop processes to the ultimate finished product and its test in service. It is the object of the scientific method to make the best of this experience, in its essential details, readily available for all concerned, and to see that it is actually absorbed and put in practice. *b* The economic result of varying executive methods for effectively directing human effort as a whole in the use of the above experience. This covers the entire field of building up, co-ordinating and controlling the supervising organization of a plant with its statistical and recording systems. *c* The economic results of steps taken to raise the industrial efficiency of the individual worker in every grade of service. This covers the whole problem of labor reward, intensified ability, conserved energy and the general relations of employer and employee."

We have pointed out that the underlying principle, the application of which has built up modern industry, is the transference of skill. This basic principle is put into effect on the management side of all industrial activities, through three regulative principles which sum up the ideas in the above quotations. These have been concisely stated as: [1](*a*) the systematic use of experience; (*b*) the economic control of effort; (*c*) the promotion of personal effectiveness.

The first includes the use, in all essential detail, of traditional knowledge, personal experience and the results of scientific study on the part of the executive force. It implies the accumulation and use of records and the setting up of standards.

The second includes the division and subsequent coordination of both executive and productive labor; the planning of single lines of effort, the setting of definite tasks and the comparison of results; and the effective training of the workers. It implies the previous acquisition of skill by the executives.

The third includes a definite allotment of responsibility and the adequate, stimulative encouragement and reward of both executive and productive labor; the development of contented workers, and the promotion of their physical and mental health. It implies the most thorough comprehension of the human being.

THE PRACTICE OF MANAGEMENT.

As labor-saving management springs from a change in mental attitude, the beginning of its practice should be with persons having the final responsibility, the proprietors of closely-owned businesses, the directors of larger establishments, or the officials having charge of Government works. Before any changes are made, such men should clearly understand the viewpoint from which all managerial work is done, the principles that are to be applied, the general method of their application and the results expected.

A similar mental attitude must be fostered among all the members of the executive force and a period of training for them begun. This may include a re-distribution of function and responsibility, and will include a detailed study of production by scientific methods. This is the period of division of thought, training of the management staff and setting up standards of performance. This must be carefully performed before there can be effective transference of skill to the workers in the production departments.

The usual conception of modern management is that it affects the workmen most of all, tending to stimulate them to turn out increased production to their possible hurt. This is wrong. If the principles outlined are followed, the executive, or non-producing labor is the most affected. It's individuals are compelled to study, plan and direct. They must acquire knowledge and skill in order to transfer it. It is a system of management that forces the executives to manage.

This being so, the introduction of modern management in a plant must be made slowly. The causes of most so-called failures are principally two: a failure of the executives to acquire the vital mental attitude, and too great haste in application. The latter seems to be the dominant one. We must emphasize the danger of attempting to hurry any change in methods of management. Each step of the work should be made permanent before the next is begun.

We have examined records of production which clearly show a lessening of individual output among workers who have been trained for some time and have achieved good results, as soon as untrained workers were put with them, thus lessening their share of personal supervision. Later the original standard of production was again reached, but the results seemed to be directly proportional to the amount of skilful supervision, during a lengthy period of training.

After those who are to operate the new methods have acquired the necessary knowledge and established sufficient standards, the work of putting these into effect can be begun. This means the fixing of the best attainable working conditions and giving each worker definite tasks with an adequate reward to each one who attains the standard set. This part of installing the method must be accomplished with tact and patience, remembering that leadership and example are powerful aids in bringing about enthusiastic co-operation.

The training of the workers is essential in this part of the application. This must be far more than mere demonstration, the mere showing that a thing can be done. It must be patient teaching and help until the required degree of dexterity or skill is acquired, that is, up to the habit stage.

Such, broadly, are the three steps in the practice of management. It is now necessary to investigate the

[1] *American Machinist*, vol. 36, p. 857, "The Principles of Management," by Church and Alford.

internal elements of permanence in such methods. If the proper mental attitude is once taken, we believe it will never be given up. Thus in a given industrial organization this feature would not be lost except by a loss of the executive staff.

The permanence of records of performance and standards need only to be mentioned to be appreciated. Once set up in an industry, disaster is invited if they are disregarded.

To these is added a third in the nature of a spur from the working forces to the managing force. An adequate reward is one of the essentials. Whatever disturbs the mechanism of production interferes with the earning of the rewards. The workers at once object, pointing out the trouble and insisting that it be rectified. The management is spurred to keep all conditions up to the fixed standard.

The practice as outlined, while built upon fixed standards and procedure, is by no means rigid and inflexible as has been alleged. The design and construction of labor-saving machinery is carried on with a multiplicity of different details. Labor-saving management should likewise use a variety of details suited to the requirements of different industries and plants. There can be nothing fixed in such human endeavor except the underlying principle. This idea of rigidity is repudiated by some of the foremost management experts.

We have emphasized the need of a scientific study of everything connected with production. The methods used are adopted from the research laboratory, but with the difference that while with the laboratory investigator the discovery of facts is his end and aim, the management investigator uses laboratory methods to discover facts for immediate use. The end and aim is utility, which is the test of industry.

The position of the expert in the practice of management is more clearly seen as experience increases. The element of mystery has already departed. This is to be welcomed for it means the downfall of mere "systematizers." *One of the unfortunate features of this great movement has been the rise of alleged experts who have been ready to promise extravagant results if they were allowed to systematize an industrial plant. The test which their work cannot meet is the one of permanence.*

An industrial manager who has had signal success in directing large enterprises sums up the more undesirable characteristics of systematizing practice as:

a. The publication and quotation of statistics regarding gains made through the use of particular systems, without a frank statement of the degree of inefficiency of the plants before reorganization.

b. The failure to view the plant from the investor's standpoint rather than as a laboratory offering opportunities for interesting and expensive experience.

c. The failure to admit that every application of past solutions to unstudied new and different conditions is an experiment.

d. The waste of time and money on problems that will yield to scientific treatment, but which do not recur often enough to justify such a solution.

e. The undervaluing of effective leadership in management and consequent lack of permanency in results.

f. The overvalue of emasculated "system" leading to a curious non-responsibility on the part of any person for the total result.

g. The frequent assumption that the treatment of the problems of similar plants should be identical.

h. The failure to properly appraise in a growing concern the value of its internal asset of "good will."

i. The imperfect analysis and appreciation of the human factor in industry, with a consequent failure to reckon patiently with "habit" and "inertia" and a tendency to hasty "substitution," bringing about the breaking up of valuable organizations.

The real expert concentrates on the facts of a given problem, and from a wide experience in analysis, co-ordination and practical responsibility works out a solution by scientific methods, suited to the material and human factors involved. The tendency is for him to do less of the detail work in installation, but to train and direct the persons who are permanently to manage. This is a true process of transference of skill.

BROAD RESULTS OF LABOR-SAVING MANAGEMENT.

In cases where the use of labor-saving management can be considered a success, the broad results have been: A reduced cost of product; greater promptness in delivery with the ability to set and meet dates of shipments; a greater output per worker per day with increased wages; and an improvement in the contentment of the workers.

This last item is shown by the fewness of strikes under the new management, and in the refusal of those working under the changed conditions to join in a strike of their fellows in the same plant who were not working under the new methods. This last-mentioned situation has arisen a number of times. In one case an attempt was made to strike a room where about one half of the operators were under the new conditions. These refused to go out; the rest went.

These results indicate certain advantages to both employer and employee, but it is charged that the movement has not yet entirely justified itself from the economic viewpoint, for it has not reduced the cost of product to the consumer. The implication is that its possibilities will not be realized until employers, employees and the public are alike benefited. With this view we are in most hearty accord. Labor-saving machinery has brought the comforts that we all enjoy to-day. Labor-saving management promises to extend those comforts. Where properly administered it is conserving labor and is thus contributing to the good of society at large, and although the benefit to the consumer may not yet be generally felt, it has already developed to a certain extent and will continue to develop as the natural result of increased production.

Following is a list of the industries in which some form of labor-saving management has been installed:

Book binding
Building construction
Carriage and wagon building
Construction and repair of vessels (navy yards)
Fire arms and ordnance
  Rifles
  Gun carriages
Machinery building
  Automobiles
  Agricultural implements
  Coal-handling machinery
  Electrical machinery
  Founding, iron and brass
  General machine work
  Gas engines
  Locomotives
  Machine tools
  Molding machines
  Pumps
  Pneumatic tools
  Sewing machines
  Typewriters
  Wood-working machinery
Metal and coal mining
Metal working
  Bolts and nuts
  Chains
  Hardware
Tanks
  Tin cans
  Valves and pipe fittings
Miscellaneous manufacturing
  Beer
  Beet sugar
  Boxes (wood and paper)
  Buttons
  Clothing
  Cordage
  Food products
  Furniture
  Flour
  Glass
  Lumber products
  Pianos
  Paper and paper pulp
  Rubber goods
  Soaps
  Shoes
  Slate products
Printing and lithographing
Railroad maintenance of motive power
Steel manufacture
Textile manufacture
  Woolens
  Cottons
  Bleaching and dyeing
  Velvets

The Camphor Industry in Formosa

An Important Japanese Monopoly

IN the German trade review *Der Kaufmann und das Leben* Mr. F. Wertheimer gives a general survey of the commercial development of Formosa, from which we cull here certain passages relating in particular to the camphor industry:

Among the several industries controlled by Japanese government monopolies the most important is the manufacture of camphor, which, after much fluctuation, finally gained a firm footing through the establishment of such a monopoly. Since 1855, when Americans made the first exports of camphor from Formosa, there has been a checkered sequence of open competition, private and government monopolies. Prices were in constant fluctuation, and no one gave any thought to the replacement of the ancient stock of camphor trees which had been cut down in the plains of the island, so as to provide for the future interests of the industry. For it must be remembered that the camphor tree does not reach its full value until it is two hundred years old. To-day a monopoly is firmly established, but the camphor tree has well nigh disappeared from the western plain, and in fact from west of its original habitats on the island. One has to go up into the high mountain regions if one wishes to see camphor furnaces at work. In these parts it has been found necessary to provide special police stations to protect the furnaces from the hands of the natives. The Japanese are working systematically to improve on this state of affairs. The licensees, who have permission to fell trees and extract the camphor, are carefully watched, and many thousands of camphor trees are being planted in the plains and upon the mountain slopes, so that there are good prospects now for a return, in time, to more favorable conditions of production. The government purchases all the crude camphor and camphor oil at fixed prices, and the refining is carried out in old Japan. There is however a movement now on foot to transfer this phase of the industry also to Formosa. A problem which is receiving much attention is that of the possible increase of the yield by the utilization of the smaller branches and twigs, and even leaves, of the tree, as well as the trunk, hitherto solely exploited. The recovery of the camphor is a simple enough process. The tree is felled and cut up into chips by means of a special kind of ax. The furnace is built under a simple wooden or reed shed, rather loosely put up, so that its cost is small and the loss on dismantling is negligible, when the region is spent, and the center of operations has to be moved on. The furnaces themselves also are of rather simple construction. Over a stone stove is placed a kettle covered with a wire screen and provided with a bamboo feed pipe through which fresh water can be admitted during the process. Over the wire screen is fitted a wooden distilling tub which receives a charge of camphor wood chips from above and is then tightly closed by means of clay. The fire heats the water in the kettle, and the steam enters the tub containing the camphor wood, heats the latter, and carries off the camphor through a bamboo pipe into a cooler in which the camphor vapors are condensed. The primitive method formerly used in Japan consisted in extracting the shavings by boiling them with water, and collecting the vapors of camphor and steam rising therefrom. This method is hardly ever used nowadays. The cooler consists of two chests nested one within the other, the lower being traversed by a constant stream of cooling water, while the upper one serves to collect the camphor. This upper chest is divided into seven compartments by wooden partitions, and the camphor vapor passes from compartment to compartment through perforations in the wooden partitions. The tub holds about 250 pounds of shavings, and about 24 hours are required to work up a charge. The dried extracted shavings are used as fuel in the furnaces. The cooler is cleared once a week of its contents of camphor crystals and oil. The camphor thus recovered is pressed free from oil and goes to Taihoku to be refined at the works of the monopoly. The export of camphor amounted to 2.25 million yens* in 1896 and rose to 4.37 millions in 1909; in 1911 it had fallen to 3.46 million yens. These figures do not include the crude camphor oil.

* The Japanese yen is almost exactly equal to the American dollar.

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Patent Solicitors,
361 Broadway,
New York, N. Y.

Branch Office:
625 F Street, N. W.,
Washington, D. C.

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

NEW YORK, SATURDAY, NOVEMBER 1, 1913

Published weekly by

Munn & Company, Incorporated, Charles Allen Munn, President
Frederick Converse Beach, Secretary and Treasurer
all at 361 Broadway, New York

Entered at Post Office of New York, N. Y., as Second Class Matter
Copyright 1913 by Munn & Co., Inc.

The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) . . . . " 3.00
American Homes and Gardens . . . . " 3.00

The combined subscription rates and rates to foreign countries including Canada, will be furnished upon application

Remit by postal or express money order, bank draft or check

Munn & Co., Inc., 361 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

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